Devils Lake, North Dakota Downstream Surface Water Users Study

Prepared for: U.S. Army Corps of Engineers St. Paul District

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Devils Lake, North Dakota

Downstream Surface Water Users Study

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The findings in this report are based on the assumptions given in the preliminary Devils Lake emergency outlet design and operating plan (*Devils Lake Emergency Outlet, Independent Assessment, Phase I*, Barr Engineering Company, October 30, 1997). The preliminary outlet operation assumed that water would be pumped out of the West Bay of Devils Lake into the Sheyenne River, and would be limited by the 450-mg/L sulfate standard at the insertion point, the 300-cfs pumping capacity, and the 600-cfs minimum bank-full channel capacity.

During the course of this study, other pumping alternatives were being examined that would tap fresher water sources and perhaps use more restrictive water quality criteria to reduce downstream effects. The results of the analysis of those later investigations will be presented in an addendum to this report.

Because of the relatively high concentration of dissolved solids in Devils Lake, pumping water from the lake into the Sheyenne River will affect the water quality in the river. It will also affect the water quality in the Red River of the North, into which the Sheyenne River drains. This study addresses the potential impacts that the changes in water quality may have on users of the water from the two rivers.

For this study, the river water users were separated into four groups: (1) Municipal water treatment facilities, (2) Industrial river water users, (3) Other permitted river water users, and (4) Non-permitted river water users. A separate analysis was conducted for each of the four groups. While the analysis was general, the costs presented in this report are based specifically on sample water quality time series ("trace") data provided by the Corps.

Municipal Water Treatment Facilities—Based on analysis of the available data regarding the operations of the eight affected municipal water treatment facilities, a computer spreadsheet model was developed to estimate each facility's annual increase in cost that can be expected due to the change in water quality. Cost increases will result from increased softening costs (due to increased chemical feed rates and increases in sludge handling and disposal), and increased capital and operations costs if treatment or an alternative water supply is required to restore the treatment facility finished water quality to without-outlet conditions.

Modeling showed the total annualized cost for increased softening will range from \$25,000 per year to \$56,000 per year, depending on the modeled water quality future. The total annualized cost for capital improvements or alternate source water development required to bring the with-outlet product water to the water quality of without-outlet product water ranged from \$1,757,000 per year to \$3,304,000 per year. In most cases, treatment by ion-exchange was found to be the least-cost alternative if without-outlet product water quality is required.

Industrial Water Users—Interviews were conducted with all of the industrial river water users along the Sheyenne River and the Red River of the North. Only two were expected to incur increased costs as a result of the Devils Lake outlet operations. The sugar beet processing facility is expected to have increased lime softening costs as a result of the outlet. The coal-fired power plant's increased costs relate to additional need for ion exchange water purification for boiler water.

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Based on one of the sample water quality data sets, annualized costs would be expected to be \$1,200 per year for the sugar beet processing facility, and \$30,700 per year for the power plant.

Other Permitted River Water Users—For this portion of the study, permit holders along the Sheyenne River and Red River of the North were first identified and characterized. Two hundred one (201) permits (excluding municipal and industrial permits) were listed along the affected reaches of the two rivers. Ninety-six percent of the permittees used the water for irrigation (which is defined to include livestock watering), and the remaining 4 percent were for other uses. Interviews were conducted with a representative sample of 20 percent of the permit holders. Approximately half of those interviewed expressed concern over possible changes in water quality, but approximately 25 percent were unconcerned. Research into salinity effects on plants and animals showed that limited potential exists for adverse effects. Potentially affected uses were identified—these include irrigation of approximately 17 square miles of corn, certain plants and vegetables, and possibly fish and livestock production. Water supply alternatives considered included a change to less sensitive crops, private well installation, connection to municipal or rural water supply systems, and relocation. However, if an alternative water supply is in fact required, payment to compensate for reduced yields may be the only practical option.

Non-Permitted River Water Users—A principal difficulty in characterizing the potential effects on non-permitted users was locating those users; agency listings of such users are unavailable. Permits for river water use are required only when certain withdrawal thresholds are reached. Twenty-five non-permitted users along the affected reaches of the two rivers were located and interviewed. Most of the non-permitted group uses the water for watering lawns, private landscape, or relatively small-scale fruit and vegetable plots. Nine of those interviewed reported using the water for livestock. Water supply alternatives identified included a change to less sensitive crops, private well installation, connection to municipal or rural water supply systems, and relocation. Alternative water supply costs expected by users varied greatly; verification of these estimates was not within the scope of this study.

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2.1 Project Background

Devils Lake is located in a closed basin in northeastern North Dakota. In the last five years, the lake has risen over 20 feet, from 1422.5 (feet above mean sea level) in 1993 to 1444.7 in 1998. This is the highest elevation recorded since record-keeping began in 1867, when the lake was at 1438.4. If the lake continues to rise, it would start overflowing into Stump Lake at 1446.6. If the lake were to reach 1459, it would overflow into the Sheyenne River and the lake water would flow, ultimately, to the Red River of the North.

Rising lake levels have affected communities, transportation routes, and rural lands. Federal, State, and local agencies have adopted a three-part integrated approach to flood damage reduction in response to the rising lake levels. This approach includes:

- 1. Upper basin water management to reduce the amount of water reaching the lake.
- 2. Protection for structures and infrastructure in case the lake continues to rise.
- 3. An emergency outlet to release some lake water.

2.2 Purpose of Study

In 1997, Congress passed Public Laws (PL) 105-18 and 105-62 dealing with the emergency outlet. PL 105-18 authorized the U.S. Army Corps of Engineers (Corps) to do planning, engineering, and design for an outlet and to prepare an Environmental Impact Statement. PL 105-62 set aside funds to initiate construction of an outlet, but final approval is contingent on the Corps reporting to Congress on several issues.

This study addresses the potential impacts associated with operation of the emergency outlet. Specifically, it examines the potential water quality impacts and water supply alternatives for consumptive users of river water in the Sheyenne River and Red River of the North downstream of the emergency outlet. The study is intended to identify downstream water users who might be affected by outlet operations, to identify water supply alternatives for those adversely affected, and to estimate the costs of those alternatives based on expected changes in downstream water quality. Figure 1 shows the study area.

2.3 Overall Approach

2.3.1 Scope of Study

The scope of this study is centered upon the assessment of possible impacts to downstream river water users associated with operation of an emergency outlet. The Water Quality Impacts Appendix of the *Emergency Outlet Plan, Devils Lake, North Dakota*, 12 August 1996 says "The water quality of Devils Lake differs considerably from that of the Sheyenne River and Red River of the North, most notably with respect to its higher salinity and the relative proportion of the major ions."

For the Sheyenne River and the Red River of the North, the principal cations are calcium, sodium, and magnesium, and the principal anions are bicarbonate and chloride, with less than 25 percent of total dissolved solids (TDS) composed of sulfate. In Devils Lake, the principal cation is sodium and the principal anion is sulfate. About 50 percent of TDS in Devils Lake is sulfate.

Because of the above water quality differences, discharges from Devils Lake to the Sheyenne River (whether from an emergency outlet or natural overflow) will affect downstream constituent concentrations to differing degrees—the concentrations are generally highest in the upstream reaches, and lower in the downstream reaches where dilution by tributary and local inflows reduces the effects. This study addresses potential impacts on and water supply alternatives for "consumptive users" of the river water, i.e., municipalities, industries, irrigators, etc., that withdraw water from the Sheyenne River and Red River of the North.

This study is just one of several ongoing and planned investigations intended to address concerns about downstream impacts related to outlet operation. Potential ecosystem effects and mitigation needs will be covered by other studies; those studies would consider (for instance) potential effects on the downstream fishery and resulting impacts on recreational users. Other studies will also assess effects on downstream erosion and sedimentation rates, which may result in changes in total suspended solids (TSS) and turbidity, and impacts of these changes on stream users.

This study considers permitted and otherwise identifiable municipal, industrial, and agricultural surface water users of the Sheyenne River (from the point of insertion of the Devils Lake outlet releases upstream of Warwick, North Dakota, to the confluence with the Red River of the North) and the Red River of the North (from the confluence with the Sheyenne River to Lake Winnipeg in Manitoba).

For this study, surface water users are divided into the following four categories:

- 1. Municipal water treatment facilities drawing water from the river.
- 2. Industrial river water users.
- 3. Other (untreated) permitted river water users.
- 4. Non-permitted river water users.

The study includes a separate and distinct analysis of the impacts on users in each category.

2.3.2 Emergency Outlet Assumptions

Downstream impacts from an outlet will be controlled to a large degree by the location, configuration, and operating plan of the emergency outlet. The final design and operating plan for the outlet have not yet been determined; therefore, preliminary outlet plans had to be used as the basis for this analysis. The findings in this report are based on the assumptions in the preliminary Devils Lake emergency outlet design and operating plan (*Devils Lake Emergency Outlet*, *Independent Assessment, Phase I*, Barr Engineering Company, October 30, 1997), as described below. This plan assumes that the location of the outlet is just south of the City of Minnewaukan, and that the pump station draws water from the West Bay of Devils Lake. The operating plan included the following:

- a. The emergency outlet will be operated only when the lake exceeded some "trigger elevation," assumed for this study to be 1430 MSL.
- b. Outlet operation will be limited by the following, the most restrictive of which will control at any time:
 - (1) Combined Sheyenne River and outlet release flows must not cause exceedance of the 450 mg/L sulfate standard for the Sheyenne River.
 - (2) The combined flows must not exceed 600 cfs, the minimum channel capacity of the Sheyenne River within the affected reach. This is to protect against inducing or contributing to flood damages.
 - (3) The emergency outlet maximum pumping capacity is 300 cfs.
- c. Outlet operation will be limited to the May–November operating year, as planned in preliminary studies.

Changing the location and/or operating regime for the pump station would likely result in a change in the downstream river water quality. The water quality of the receiving rivers would be affected by any changes to the assumed design and operating plan that result in pumping more or less water, or in pumping water of different quality than that assumed in the current plan. For example, the location of the pump station may be changed to position it closer to the lake's inflow sources, thus allowing the pump station to send fresher water to the Sheyenne River. Or, the operating limitations on the pump station may be revised to allow a longer operating season each year. Similarly, the water quality criteria applied to the Sheyenne River—criteria that affect the allowable rate of pumping from Devils Lake—may become more or less stringent.

Because the results of this study are contingent on the trace data that reflect the water quality in the Sheyenne River and Red River of the North, changes to the assumed outlet design and operating plan for the trace data will change the study results. During the course of the present study, the Corps of Engineers was in the process of evaluating several other alternatives for the emergency outlet design and operation. The results of the analysis of those alternatives will be presented in an addendum to this report.

2.4 Organization of Report

The main body of this report consists of four sections, each discussing the analysis of one of the four water user categories described above. Each of the four sections consists of four subsections: Purpose, Methodology, Results, and Discussion.

Section 3: Municipal Water Treatment Facilities—Describes the analysis of the potential impacts on municipal water treatment facilities drawing river water that may be affected by the Devils Lake outlet. A brief description of the method of modeling the water quality changes is included. Section 3 also describes how operations information for the facilities was collected, the methods of estimating any increases in operating and capital costs, and presents the results of the cost estimates.

Section 4: Industrial River Water Users—Identifies the industrial river water users and the types of use. The potential effects of the water quality changes on industrial users are also described. The methods of estimating the increased operating costs for potentially affected users are discussed, and the resulting cost estimates for industrial users are given.

Section 5: Other (Untreated) Permitted River Water Users—Details the methods used for identifying the permitted users and assessing their concerns. It identifies the purposes of river water withdrawals along the Sheyenne River and Red River of the North and lists the concerns noted by each of the user groups. Potential effects are explained, and potentially affected users are identified. Water supply alternatives are later summarized and discussed. A general discussion of those alternatives' costs is included.

Section 6: Non-Permitted River Water Users—Tells of the methods used to locate and contact non-permitted users of Sheyenne River and Red River of the North water. Types of non-permitted water uses are given and the concerns of this user group are listed. Concerns and possible water supply alternatives are discussed.

Background information and additional data are included in the appendices as follows:

Appendix A: Water Treatment Facility Information Summaries—Contains detailed information that was obtained directly from each of the water treatment facilities.

Appendix B: Mitigation Model User's Manual—Details the steps necessary to analyze future traces of water quality concentrations using the spreadsheet model that was developed as part of this study. The manual also contains example pages from the spreadsheet.

Appendix C: Permit Holders Listed between Trace Data Stations—Lists all permittees identified on state and provincial listings, organized between trace data stations. The table also lists the permittees' use, state or province, and permit number.

Appendix D: Permit Holder Additional Data—Lists permittees by state or province. Data in these tables were taken directly from the available state or province information, including (as available): type of water use, use appropriation, reported water use, permit number, and county.

Appendix E: Information Summaries: Permitted Users—Describes the information obtained through our contacts with individual permitted users.

Appendix F: Information Summaries: Industrial Users—Describes the information obtained through our contacts with each of the industrial users.

Appendix G: Selected Soils, Irrigation, and Fisheries Publications—Includes reprints of selected publications that provide information regarding irrigation of crops, suitability of soils for irrigation, and affect of water quality on livestock.

Appendix H: Information Summaries: Non-Permitted Users—Describes the information obtained through our contacts with individual non-permitted users.

Appendix I: Phase I Present Worth and Annualized Costs, by Trace and Treatment Facility—Lists the Phase I costs for treatment to without-outlet concentrations of total hardness for each of the water treatment facilities. Costs are listed by trace number.

Appendix J: Phase II Present Worth and Annualized Costs, by Trace and Treatment Facility—Lists the Phase II costs for treatment to without-outlet concentrations of total hardness and total dissolved solids for each of the water treatment facilities. The technology that was assumed for the Phase II treatment at each facility is also listed. Costs are listed by trace number.

Appendix K: References—Lists references for the published materials used for this study.

3.0 Municipal Water Treatment Facilities

3.1 Purpose and Scope

The purpose of this portion of the study was to identify permitted municipal water treatment facilities that use river water and whose function and performance might be affected by changes in river water quality caused by Devils Lake outlet operations. A subsequent task was to identify mitigation alternatives for those adversely affected and estimate costs of mitigation based on the anticipated changes in the river water quality downstream of the Devils Lake outlet. Only permitted municipal facilities that use river water were considered for this investigation.

For each treatment facility identified, the source water quality constituents that may influence facility performance in meeting treatment standards were identified. A two-phased approach was then taken to develop a mitigation model for each treatment facility. Phase I estimated the operating costs related to reduction of carbonate and non-carbonate hardness to without-outlet operation conditions. Phase I also identified which water quality constituents would be above the secondary standards after hardness is restored to without-outlet operation levels.

For Phase II, estimates were made of the cost of additional hardness removal and additional treatment that would be required to bring the with-outlet finished water quality to the without-outlet finished water quality. Costs for any expansion, modification, or replacement of treatment facilities made necessary by outlet operation were estimated. Costs of developing an acceptable alternate water source—possibly requiring similar treatment or no additional treatment—for substitution or blending with the with-outlet river water were determined. Finally, the most cost-effective alternative (treatment or alternate water supply) was identified for Phase II.

3.2 Methodology

3.2.1 Downstream Constituent Concentrations

To determine the potential impacts on water treatment facilities, methods were required to calculate future water quality constituent concentrations in the Sheyenne River and Red River of the North for two potential futures—without and with the emergency outlet. Because Devils Lake is a landlocked lake, the range of future water level and water quality fluctuations is more difficult to calculate than for a simpler surface water system (such as a river basin). Future lake levels and

quality are affected by a variety of climatic factors, by the lake level in previous years, and by the elevation of the surficial aquifers.

Potential future lake conditions—or "futures"—for the lake were produced from a lake level model developed by the United States Geological Survey (USGS). This USGS "5-box" (with each of the five "boxes" representing a major portion or bay of Devils Lake) water and water quality mass balance model stochastically generates "50-year traces" representing possible lake futures. Each trace represents a slightly different lake level future. The 50-year trace outputs from the 5-box model include lake elevations and water quality, outlet flows and water quality, and Sheyenne River flows and water quality at the insertion point. Assuming no pumping would occur from the lake, a first set of 10,000 traces of future lake levels and water quality parameters was created.

This same set of traces was then run with outlet operation to produce corresponding pairs of withand without-outlet traces and related lake elevations and water quality along with Sheyenne River flows and water quality at the insertion point.

To assess the downstream water quality effects of pumping from Devils Lake into the Sheyenne River, the Corps developed a HEC-5/5Q river and reservoir model for the Sheyenne River and Red River of the North. The HEC-5/5Q model routes the 5-box model's output down the Sheyenne River and Red River of the North to estimate possible downstream flow and water quality. The HEC-5/5Q model was used to track TDS, sulfate, chloride, and hardness, which were assumed to be conservative substances and were modeled as such. A conservative constituent is one for which the concentration is directly related to the extent of dilution, i.e., the substance is not decomposed, altered chemically, or removed physically as a result of natural processes. The model was not used to track non-conservative substances, such as nitrogen, phosphorus, total organic carbon (TOC), dissolved oxygen, biochemical oxygen demand (BOD), and pH, whose pathways are far more complex. Output from the HEC-5/5Q model allows determination of representative ranges, concentration duration, and concentration frequency of water quality constituents.

From the 5-box model output, seven of the 10,000 without-outlet traces, and seven corresponding with-outlet traces (each corresponding to the same lake level future as one of the selected without-outlet traces) were selected for analysis of downstream effects. The seven trace pairs are representative of lake futures ranging from a slow rise in lake level and maximum output from the proposed outlet to an immediate drop in lake level and minimal use of the outlet. The descriptions in Table 3-1 (tables are found at the end of Section 3) show that the seven traces range across four of the five trace categories defined by the USGS. With the selected traces used as input for the

HEC-5/5Q model, 50-year water quality concentrations were calculated for the Sheyenne River and Red River of the North downstream of the Devils Lake outlet discharge.

These water quality concentrations—output from the HEC-5/5Q model—were then used for this study to determine potential impacts on water users along the rivers.

The complexity of the HEC-5/5Q model requires that the output only be produced at several predetermined locations ("stations") along the two rivers. The river mile for each station was identified, with the furthest downstream point (Lake Winnipeg) being river mile 0.0. The junction of the Red River and the Sheyenne River is at river mile 427.5. For the purposes of this study, the Sheyenne River miles were combined with the Red River miles; the furthest upstream point (Devils Lake outlet insertion) being river mile 890.7. The stations at which model output was tabulated mark the endpoints of eleven river reaches described below:

Reach	From	То	River
1	Outlet* (RM 890.7)	Cooperstown (RM 744.5)	Sheyenne
2	Cooperstown (RM 744.5)	Valley City (RM 680.5)	Sheyenne
3	Valley City (RM 680.5)	Lisbon (RM 589.2)	Sheyenne
4	Lisbon (RM 589.2)	Kindred (RM 495.7)	Sheyenne
5	Kindred (RM 495.7)	Junction* (RM 427.5)	Sheyenne
6	Junction* (RM 427.5)	Halstad (RM 375.2)	Red
7	Halstad (RM 375.2)	Grand Forks (RM 298.1)	Red
8	Grand Forks (RM 298.1)	Oslo (RM 271.2)	Red
9	Oslo (RM 271.2)	Drayton (RM 206.7)	Red
10	Drayton (RM 206.7)	Emerson (RM 154.7)	Red
11	Emerson (RM 154.7)	Lake Winnipeg (RM 0.0)	Red

^{*} Outlet refers to the insertion point of the proposed emergency outlet. Junction refers to the junction of the Sheyenne River and the Red River of the North.

Figure 1 shows the river reaches for the study area.

Locating the municipal, industrial, and other permitted users within one of the river reaches allowed a modeled water quality to be assigned to that user. For example, a user located in Reach 2 was assumed to be subject to the modeled trace water quality data tabulated for Cooperstown. In this way, potential effects could be assessed more realistically, with consideration made for the dilution occurring as the Devils Lake water moves downstream.

3.2.2 Examination of Pertinent Water Quality Standards

To assess the possible effects of the modeled water quality constituents tracked by the HEC-5/5Q model, the United States National Primary Drinking Water Regulations were reviewed. The primary drinking water standards (expressed as Maximum Contaminant Level Goals, or MCL goals) are shown in Table 3-2. In addition to the primary standards—health-related and enforceable standards—Safe Drinking Water Act (SDWA) secondary drinking water standards were obtained and reviewed. Secondary standards are non-enforceable federal guidelines for constituents that may adversely affect the aesthetic quality of drinking water. These standards are shown in Table 3-3.

The Canadian guidelines for drinking water quality were also reviewed to better assess the treatment goals for water treatment facilities located in Canada. The current guidelines for Canadian drinking water quality are listed in Table 3.4.

None of the constituents tracked by the HEC-5/5Q model are currently regulated under the U.S. Primary Drinking Water Regulations. Although primary standards do not apply to any of the constituents tracked by the model, sulfate, TDS, and chloride do have applicable secondary standards.

The HEC-5/5Q model does not track sodium concentrations. However, because sodium concentrations are elevated in Devils Lake, sodium concentrations are expected to be elevated in the Sheyenne River and Red River of the North as a result of pumping from the lake. Neither the U.S. nor the Canadian regulations have established a water quality standard for sodium. For reference however, research into sodium standards disclosed that the World Health Organization suggests a (non-enforceable) sodium "guideline" of 200 mg/L for drinking water. Additionally, the U.S. Environmental Protection Agency has suggested a guidance level of 20 mg/L for protection of an at-risk population (those with heart, circulatory system, liver, and kidney disease).

Several attempts were made to locate information on the forthcoming SDWA amendment's proposed standards as they relate to constituents tracked by the HEC-5/5Q model. Such information was generally unavailable. Proposed changes in the regulations could only be ascertained with respect to sulfate. Currently, there are no primary standards for sulfate; the secondary standard for sulfate is 250 mg/L. The proposed change in the regulations would establish a primary standard for sulfate, but would likely increase the allowable concentration to 400 mg/L. Because of the uncertainties with respect to the proposed regulatory standards for sulfate, treatment to reduce

sulfate was not specifically addressed in this report. However, projected sulfate concentrations are discussed in relation to the existing secondary standard and proposed primary standard.

3.2.3 Treatment Facility Identification and Investigation

To identify the water treatment facilities that may be affected by the operation of the outlet, permitted municipal users along the Sheyenne River and Red River of the North were identified. The agencies responsible for permitting were contacted: North Dakota State Water Commission, Minnesota Department of Natural Resources, and Manitoba Water Resources. A listing of the municipal water-use permittees was obtained from each of the three agencies for the portions of the rivers that could potentially be impacted by outlet operations. North Dakota listed a total of 14 permits for water treatment facilities along the Sheyenne River and Red River of the North, Minnesota listed 1 permit along the Red River of the North, and Manitoba listed 3 permits along the Red River of the North. Table 3.5 lists each municipal permit, the name of the permit holder, and the status of the permit.

Each of the permit holders were then contacted and interviewed. Several cities had obtained permits for withdrawal of water but had never constructed a surface water treatment facility and had no intention of using the river as a raw water source in the future. Other cities had at one time operated a surface water treatment facility but had discontinued operations at the facility with no intentions of constructing another. The water treatment facilities in McVille, Lisbon, Oslo, and Selkirk were eliminated from the impact study because their source of water was neither the Sheyenne River nor the Red River of the North. The City of East Grand Forks (located on the Red River of the North) does not currently have a permit for withdrawing water from the Red River. However, East Grand Forks has expressed an interest in using the river in the future and has concern over the future river water quality. Therefore, information regarding the East Grand Forks water treatment facility was also obtained (but cost estimates were not developed for this study for the East Grand Forks facility). The City of Winnipeg, although located on the Red River of the North, withdraws water from Shoal Lake chain and, therefore, is not influenced by Red River water quality.

Eight water treatment facilities were retained for further analysis. From farthest upstream on the Sheyenne River to farthest downstream on the Red River of the North, those facilities were: Valley City, Fargo, Grand Forks, Grafton, Drayton, and Pembina; all located in North Dakota; and Letellier and Morris, located in Canada. The location of each of these facilities is shown on Figure 2.

To collect necessary information regarding facility operations, interviews were conducted in person at each water treatment facility. From these interviews, as well as from several follow-up telephone conversations with operators at each facility, an information sheet was developed for each facility. (These information sheets are included in Appendix A.) Information listed includes: facility permit number, contact person, intake location, chemicals used for treatment of hardness, type of treatment processes, contingency plans, water usage, treatment efficiency, finished water quality, cost of operation, and treatment capacity. In some cases, treatment facility operators were unable or unwilling to supply certain information; the information sheets show these data as N/A (not available). The listings of chemicals used (Appendix A) vary from one treatment facility to the next; these variations reflect differing modes of treatment and differing treatment objectives for the individual facilities. Monthly raw water usage for the North Dakota facilities for the years of 1996 and 1997 were obtained from the North Dakota State Water Commission.

Because of the difficulty in obtaining complete data for each of the treatment facilities, data-gathering efforts were focused on high-volume users furthest upstream. These users are Valley City, Grand Forks, and Fargo. Examination of the water quality traces showed that these users would be affected most by the proposed outlet from Devils Lake, so the overall treatment facility cost increases resulting from the Devils Lake outlet depends heavily on how these users are affected. Development of accurate cost estimates for these users was, therefore, felt to be most important, so that gathering accurate operations data for these facilities was most critical. By contrast, any cost increases projected for the lower-volume facilities further downstream (Pembina, Letellier, and Morris) would have less effect on the overall treatment facility costs. For expediency, therefore, cost and operations assumptions (such as using similar cost and operational data supplied by the high-volume users) were made when necessary to supplement operator-supplied data for developing mitigation costs for the lower-volume facilities further downstream.

3.2.4 Trace Data Management and Manipulation

The river water quality data used in this study were output from the HEC-5/5Q model, as explained in Section 3.2.2. The HEC-5/5Q model output for the seven traces listed in Table 3-1 show fluctuations in five water quality parameters (total dissolved solids, sulfate, chloride, total hardness, and non-carbonate hardness) at eleven locations ("stations") along the Sheyenne River and the Red River of the North. Each of the traces was developed for both "with-outlet" and "without-outlet" conditions. Through consideration of the location of the eleven stations with respect to the locations of the water treatment facilities to be analyzed, six stations were selected for evaluating the economic effects of the outlet on drinking water treatment facilities downstream. Table 3.6 lists

each of the eight drinking water treatment facilities evaluated in this study, along with the corresponding HEC-5/5Q station that was used to represent the "with-outlet" and "without-outlet" water quality. The trace without-outlet raw data were compared to the raw water quality data provided by each treatment facility to assure that projected without-outlet water quality was similar to existing water quality.

It should be emphasized that the five water quality parameters modeled for each of the traces were chosen (by the Corps of Engineers) because they are commonly of interest with respect to water treatment and water use, and could be assumed to be conservative substances. However, non-conservative constituents that may also be of interest for water treatment investigations (e.g., pH, TOC, and BOD) were not investigated in this study.

Although sodium concentrations were not generated for the trace output, they were of interest when examining water treatment and water use. Therefore, a method was developed to provide estimates of sodium concentrations. It was assumed that sodium would pair with sulfate in solution. For each of the traces, sodium concentrations were then calculated as being 45 percent, by mass, of the modeled sulfate concentration. The validity of this method of estimation was verified by examination of water treatment facilities records of raw water constituent concentrations. This relationship between sodium and sulfate was assumed to be accurate for the without- and withoutlet conditions.

Trace data were originally provided in ASCII text file format. Twelve trace data files were provided—two (one with and one without outlet) for each of the six stations pertinent to the municipal water treatment facility analysis. Each of the twelve files contained data for seven traces, each trace representing a different lake level future. The trace data files were imported into Excel (Version 97 for Windows NT) for processing. Monthly averages for each water quality constituent were computed for each trace. Monthly averages dampen the effects of data outliers—short-lived spikes in water quality constituent concentrations—while still allowing accurate evaluation of longer-term changes in water quality. The use of monthly (rather than daily, or weekly) averages for estimating water treatment facility costs provided a means by which to more closely approximate a treatment facility's response to changing water quality. Short-term (daily or weekly) fluctuations in water quality would not be expected to occasion changes in chemical treatment dosages, which would be altered only after longer term trends have been observed. In addition, the use of monthly averages allowed the use of a significantly smaller data set for mitigation cost estimating.

For each station, the with-outlet and without-outlet monthly averages were calculated from the parent files and copied into separate tabs of a single Excel file. Within the Excel file, the difference in each of the water quality parameters (with-outlet minus without-outlet) was computed for each month and placed on a third tab. These tabulations of water quality constituent concentration differences, or "deltas," one set per station, served as the main data sets for the water treatment facility mitigation models.

The water quality deltas were used as data input for both the Phase I and Phase II mitigation models. They also served to allow assessment of impacts due to increased concentrations of water quality parameters that are not affected by existing treatment at the municipal water treatment facilities. The delta values for carbonate and non-carbonate hardness were used in the Phase I model to estimate the increased water treatment cost. This cost is that required for the removal of additional hardness (as indicated by the delta values) such that the municipal water treatment facilities' finished water total hardness would be the same as the without-outlet conditions. Because the treatment facilities were seen to be capable of handling the additional hardness (as indicated by the deltas) without plant modifications, the removal of additional hardness requires only increased chemical feed costs. As such, the removal is directly proportional to the delta value.

The delta values for total dissolved solids (TDS) <u>not</u> associated with hardness were used to estimate the additional cost for treatment under the Phase II model. For Phase II, it was assumed that the with-outlet municipal water treatment facilities' finished water TDS concentration must be treated so that it would be similar to the without-outlet concentration. Phase II, therefore, added further TDS removal (by ion exchange) costs to the hardness removal costs estimated in Phase I.

The delta values were generated for each trace for each water quality constituent, and at all six trace data stations. As such, the tables listing the deltas are quite voluminous and, therefore, were not printed for this report. The tables are contained in the Excel spreadsheets used to run both the Phase I and Phase II mitigation models.

3.2.5 Development of Phase I Mitigation Model

3.2.5.1 General Considerations

As stated previously, the constituents included in the mitigation model were limited to those tracked by the HEC-5/5Q model: total hardness (both carbonate and non-carbonate), TDS, chloride, and sulfate. Review of the data obtained from each of the treatment facilities showed that for these constituents, only total hardness was used to measure facility performance. Equipment and

processes were in place at each of the facilities to meet the current finished water hardness goal. It was assumed, therefore, for the Phase I evaluation that the treatment facilities would continue to remove hardness down to their current finished water concentration targets, no matter what raw water hardness concentration resulted from the Devils Lake outlet operations. The raw water hardness values were all within the range of conventional lime-soda limitations for hardness removal.

As a preliminary step in the development of the Phase I (softening costs) model¹, the seven HEC-5/5Q traces were analyzed. The traces were analyzed with respect to their potential to cause an increase in the operating cost, or to require capital improvements to achieve softening goals. The increased operating cost was estimated by applying the delta hardness values calculated for each trace and municipal treatment facility. To determine if capital improvements were necessary to remove the additional hardness, each treatment facility's chemical feed equipment capacity was obtained to assist in determining whether additional chemical feed equipment would be required to remove the increase in total hardness for each facility. To evaluate whether or not capital improvements were necessary, the hardness delta tables for each trace and facility were reviewed and the maximum monthly delta hardness values for each facility and trace were identified. These maximum delta values were compared to the chemical feed capacity for each treatment facility.

Of the sample traces used in developing this report, Trace 6262 had the maximum increase in monthly hardness for all seven of the municipal water treatment facilities. Trace 6262 was also determined to be the trace that resulted in the largest peak delta values for the other water quality parameters. Therefore, in the following sections of this report, attention is focused on Trace 6262 as a representative example for mitigation costs that would be incurred when the outlet is operating. Traces 498 and 2848 result in a higher average monthly hardness increase during the first 15 years of the analysis, and therefore these two traces have larger mitigation costs in terms of present worth.

Hardness removal at water treatment facilities generally results in reduction of TDS concentrations. To account for this removal, each treatment facility's predicted finished TDS concentration was calculated based on the assumed calcium carbonate and magnesium carbonate hardness removal during the softening process. TDS removal rates were based on treatment

 $^{^{1}}$ For the benefit of those interested in applying the mitigation model to other HEC-5/5Q traces, a brief user's manual is presented in Appendix B.

facility records, comparing raw water and product water TDS concentrations. It was assumed that the TDS removal rates would not change under with-outlet conditions.

By contrast to TDS, it was assumed that the concentration of other constituents governed by secondary standards would not be affected (lowered) by the facilities' existing treatment processes. This assumption having been made, the anticipated with- and without-outlet concentrations for each of these parameters could be plotted. These concentrations for Trace 6262 are presented on Figures 4 through 16, which show anticipated raw and finished (Phase I) water concentrations for both with- and without-outlet conditions. The secondary standard, if it exists, is indicated on each figure for comparison to the expected concentrations.

The Phase I portion of the model assumes that only existing treatment processes are used, and that hardness removal is the principal goal in treating the with-outlet raw water. Treating for hardness will remove only some of the TDS, and is assumed to have no significant effect on sulfate concentrations. As a result, under the Phase I model (using the Trace 6262 data), the secondary standards can be expected to be exceeded for finished-water TDS and sulfate at some of the treatment facilities—Valley City, Fargo, and Grand Forks (see Figures 4, 5, 7,8, 9, and 10). However, for the Phase I cost estimates, it was assumed that the facilities would not treat for these exceedances due to the high costs involved. Inherent in this assumption is that the effects of any secondary standard exceedances on consumers of the product water would be acceptable. (The Phase II portion of the model, discussed later in this report, addresses removal of **all** of the modeled constituents to the level of their pre-outlet operation concentrations.)

Through examination of the trace data, it was seen that, in all cases, the existing chemical feed capacity was sufficient to treat the additional hardness so that no capital improvements would be necessary. Costs for capital improvements were therefore assumed to be unnecessary for the Phase I portion of the mitigation model; no new unit processes were anticipated to be required as a result of the increased raw water hardness. Anticipated treatment costs were limited to those resulting from expected increases in chemical feed, and additional chemicals required were limited to those necessary for softening treatment only. Because it was assumed that additional treatment with lime and soda ash for softening would require additional pH adjustment, additional costs for recarbonation were also included in the Phase I cost evaluation.

The increase in chemical usage was determined by calculating the chemical feed rate currently required to remove one pound of hardness at each treatment facility. The same pound for pound

dosage was used in calculating the increased chemical feed rates that would be required to treat the increased hardness caused by the outlet from Devils Lake. Because no capital improvements are required to accommodate the need for increased hardness removal (see above), hardness removal costs are dependent only on the chemical costs for treating the additional hardness. These costs are assumed to be linearly related to the hardness deltas described previously.

When possible, chemical costs were obtained from the treatment facilities. When this information was not available from a treatment facility, costs were estimated by using costs from similar facilities. All chemical costs were verified by comparison with cost data obtained from a local chemical supplier.

In addition to increased chemical costs, the need for increased softening will cause increases in sludge handling and disposal costs. For the Phase I model, the amount of additional sludge production was estimated based on current sludge production data from each facility. The cost of sludge disposal on a per-pound basis was unknown in most cases. Therefore, sludge disposal costs generally had to be estimated based on what was known about the facilities' sludge handling processes.

Most of the water treatment facilities currently discharge their lime sludge to sludge lagoons located on site. The sludge is allowed to accumulate and thicken until the lagoon has reached its capacity. At that time the lagoon is emptied and a cost is incurred for both sludge removal and disposal. This manner of infrequent sludge disposal made it difficult to assign a per-pound or even an annual cost for sludge disposal. For the purpose of this study, the sludge production rate for each facility was used along with a known or estimated lagoon capacity to estimate the number of years required for the lagoon to reach capacity. Increased softening would result in increased sludge production and a faster rate of lagoon filling. Known or estimated lagoon-emptying and disposal costs would, thereby, be incurred more frequently. By comparing with modeled without-outlet sludge disposal costs, the increased cost for the with-outlet scenarios could be established.

Although several of the water treatment facilities provided data related to several recent years of operation, those data were often incomplete. Data for 1997 were assumed to not be representative because of the severe flooding problems during the spring. However, examination of the treatment facilities' reports indicated that 1996 was a relatively average year with respect to water use in the study area. In addition, most of the facilities were able to supply fairly complete data for 1996. Therefore, most of the operations cost projections for this study were based on 1996 data for treatment facility water production, water quality concentrations, and chemical feed rates.

Using the above-stated assumptions, the Phase I model calculates the cost of mitigation for each facility by the following method: The model first calculates the average delta (with-outlet minus without-outlet) for hardness for each month of the study. The delta is calculated using treatment facility flow data and trace data concentrations. The calculated delta is then multiplied by the pounds of chemical required per pound of total hardness removed, and with this result a chemical treatment cost is calculated. Similarly, the increased production of sludge is calculated from the monthly hardness deltas. Sludge disposal costs vary by treatment facility, and are calculated as described in the discussion for each facility. The total cost of the Phase I portion of the mitigation model consists of the sum of the increased chemical feed costs and sludge disposal costs. In all cases, the costs over the 50-year modeled period are first brought back to present (1998) dollars and then annualized, based on a 1998 interest rate of 7-1/8 percent.

In the following paragraphs, the treatment facilities are described, along with the unique assumptions used in the Phase I model for the particular facility. The water treatment facilities are discussed from upstream to downstream along the Sheyenne River and the Red River of the North.

3.2.5.2 Modeling Assumptions for Valley City

Valley City is the treatment facility closest to the outlet and is therefore most likely to experience the greatest impact on its raw water quality due to outlet operations. The Valley City Public Works Water Treatment Facility was built in 1972 and has a capacity of 4.0 million gallons per day (MGD). The facility serves a population of 7,400 people with an average water usage of 1.0 MGD. During most of the year, the raw water is taken directly from the Sheyenne River. During summer months, taste and odor problems resulting from elevated algae levels in the Sheyenne make that water undesirable. As a substitute, during periods of high algae levels, raw water is instead obtained from wells located adjacent to the river. The wells are shallow and only 48 feet from the river. (Based on the well proximity to the river, it was assumed that the well water quality, in terms of the parameters modeled, was identical to that of the river water.)

Because the facility capacity is twice the current demand, it was assumed that the existing chemical feed equipment is sized at twice capacity and would be able to meet any increased demand caused by increased hardness concentrations. This assumption was verified with the facility operator.

With the exception of polymer costs, the costs of softening-related chemicals were not available directly from the staff at the Valley City treatment facility. Therefore, Valley City's costs were

assumed to be similar to those provided by the Grand Forks treatment facility as confirmed by the local chemical feed supplier.

The additional sludge production that would result due to outlet operations was estimated based on cost data provided by Valley City for emptying the sludge lagoons. The city estimated that the lagoons reach capacity approximately every 23 years, and the cost of emptying and disposing of the sludge is approximately \$75,000. Because the sludge lagoon is currently near maximum capacity, it was assumed that it would be empty at the start of outlet operation.

Based on information received from the facility, the following estimates were used in the Phase I mitigation model for Valley City:

Flow, annual average (MGD)	1.0
Target finished water hardness (mg/L)	120
Pounds of lime used per pound of hardness removed	2.64
Pounds of CO ₂ used per pound of hardness removed	0.24
Pounds of sodium aluminate used per pound of hardness removed	0.018
Pounds of polymer used per pound of hardness removed	0.0013
Pounds of sludge produced per pound of hardness removed	3.15

3.2.5.3 Modeling Assumptions for Fargo

The Fargo Water Treatment Facility was constructed in 1997 and currently serves a population of approximately 85,000 people. Fargo has a primary intake source on the Red River of the North and a secondary intake source on the Sheyenne River. The intake on the Red River of the North is located upstream of the confluence with the Sheyenne River and, therefore, it was assumed that outlet operations would not have an effect on the raw water drawn from the Red River of the North. The Fargo treatment facility also has a permit to withdraw water from Lake Ashtabula should it be necessary due to emergency conditions. The facility has a peak rated capacity of 30 MGD and an average rated capacity of 14 MGD. The average daily water use rate has been approximately 11.5 MGD.

Since only a portion of Fargo's raw water supply would be affected by outlet operations, the portion of flow typically taken from the Sheyenne had to be estimated. Fargo uses the intake on the Red River of the North as its primary raw water source due to the Sheyenne River's water quality generally being worse. The exception is when water quality in the Red River is worse than the

water quality on the Sheyenne River; on these occasions, Fargo switches to the Sheyenne River as its primary source. Because there appears to be no means of accurately predicting the timing or amount of Sheyenne River withdrawals for the Phase I model, these withdrawals were estimated by averaging the last 10 years of Sheyenne River withdrawal data.

Since Fargo's treatment facility is relatively new, the capacity of the chemical feed equipment was determined to be more than adequate for the anticipated increased hardness concentrations resulting from outlet operations.

Although the Fargo staff was able to provide the approximate cost of softening chemicals on a pergallon-of-water-treated basis, the cost range provided by the facility was too wide to be of use for the cost model. Therefore, it was assumed that all chemical costs, except polymer costs, would be similar to those of Grand Forks. Grand Forks data were used since it is the next largest facility, and the cost data provided by Grand Forks were more readily usable for modeling purposes. The polymer cost was assumed to be equivalent to that obtained for Valley City.

Fargo indicated that they dispose of their dewatered sludge on a daily basis by hauling it to the landfill as daily cover. The cost of additional sludge disposal was estimated by assuming a monthly cost for landfill disposal (based on "tipping" fees). Estimates of tipping fees were based on information obtained from the City of Fargo.

The following estimates were used in the Phase I mitigation model for Fargo:

Flow, annual average (MGD)	11.5 Total 0.83 Sheyenne
Target finished water hardness (mg/L)	110
Pounds of lime used per pound of hardness removed	1.05
Pounds of soda ash used per pound of hardness removed	0.32
Pounds of CO ₂ used per pound of hardness removed	0.24
Pounds of sodium aluminate used per pound of hardness removed	0.053
Pounds of polymer used per pound of hardness removed	0.011
Pounds of sludge produced per pound of hardness removed	8.25

3.2.5.4 Modeling Assumptions for Grand Forks

The City of Grand Forks Water Treatment Facility, installed in 1897, has undergone several upgrades over the years. The facility has a capacity of 16.5 MGD but produces an average of approximately 8.0 MGD and serves approximately 55,000 people. Grand Forks obtains approximately 60 percent of their raw water from the Red Lake River and approximately 40 percent from the Red River of the North. Water from the two sources is blended, with the exact proportions depending on the water quality in each river. The Red River of the North is normally a little harder, but lower in TOC than the Red Lake River. Therefore, although Grand Forks has an alternate raw water supply (the Red Lake River) should the water from Red River of the North water quality be greatly degraded, the elevated TOC concentrations in the Red Lake River make it an undesirable source at certain times of the year. For purposes of this study, it was assumed that the city would continue to withdraw water from its two sources at the current proportions.

The capacity of the Grand Forks water treatment facility is approximately twice the current average daily demand. It was, therefore, assumed that the capacity of the chemical feed equipment would be adequate to handle the increased dosages required by outlet operation effects. This assumption was verified with the facility operator. The city provided detailed information on the cost of their chemicals and these data were used in the mitigation model for Grand Forks.

The city also provided sludge production data. The Grand Forks water treatment facility dewaters its sludge using vacuum filtration, and then hauls it to the city-owned landfill for final disposal. Although the water treatment facility is not billed directly for the landfill disposal, costs for disposal nevertheless exist and were included in the Phase I model. A sludge disposal fee of \$25 per ton was assumed to represent landfill tipping fees.

The following estimates were used in the Phase I mitigation model for Grand Forks:

Flow, annual average (MGD)	8.0 Total 3.2 Red Lake
Target finished water hardness (mg/L)	145
Pounds of lime used per pound of hardness removed	1.66
Pounds of soda ash used per pound of hardness removed	0.1
Pounds of CO ₂ used per pound of hardness removed	0.44
Pounds of sludge produced per pound of hardness removed	11.0

3.2.5.5 Modeling Assumptions for Grafton

The Grafton Water Treatment Facility, installed in 1954, serves 5000 people and has a facility capacity of 3.0 MGD. The daily average water usage was 0.7 MGD in 1997 with approximately 90 percent of the facility's raw water coming from the Red River of the North and 10 percent from the Park River. According to reports received from the City of Grafton, the Park River has a substantially higher total hardness concentration than the Red River of the North, so that the Red River of the North is the raw water source of choice. The Park River is used as a water source for Grafton during spring runoff or during periods when the water from the Red River of the North is less desirable. The Park River is also used as a backup supply in cases where mechanical or electrical malfunctions interrupt operations at the Red River. Similarly, the Park River is used when electrical suppliers restrict electrical use at the Red River of the North pumping station.

In evaluating the need for capital improvements required to treat additional hardness at Grafton, Trace 6262 raw water with- and without-outlet hardness concentrations were compared. The trace data showed that the with-outlet hardness was only elevated by an average of 5 mg/L over the average without-outlet concentration of approximately 250 mg/L. Based on this average increase of only 2 percent, it was assumed that the existing chemical feed equipment would be adequate to handle the increased chemical feed rates required due to outlet operations.

Chemical costs were obtained directly from water treatment facility staff.

Sludge production data were not available from the Grafton facility and were estimated based on data from other facilities. Specifically, the sludge production rate on a per-pound-of-hardness-removed basis was assumed to be similar to that at Valley City. Similarly, the per-pound sludge disposal cost was assumed to be equal to that of Valley City. Grafton supplied an estimated cost of \$90,000 every eight years for sludge disposal, and this cost was used in the model.

The following estimates were used in the Phase I mitigation model for Grafton:

Flow, annual average (MGD)	0.7
Target finished water hardness (mg/L)	127
Pounds of lime used per pound of hardness removed	0.98
Pounds of soda ash used per pound of hardness removed	0.26
Pounds of CO ₂ used per pound of hardness removed	0.27
Pounds of sodium aluminate used per pound of hardness removed	0.036
Pounds of polymer used per pound of hardness removed	0.00094
Pounds of sludge produced per pound of hardness removed	3.15

3.2.5.6 Modeling Assumptions for Drayton

The Drayton Water Treatment Facility was installed in 1962, with expansions and upgrades occurring in 1994, 1995, and 1996. The city uses the Red River as its raw water source and serves a population of approximately 1,000 people. The maximum capacity of the facility is 0.72 MGD and the average raw water intake is 0.25 MGD. The Red River of the North is the sole raw water source for the Drayton Water Treatment Facility.

In evaluating the need for capital improvements required to allow softening to continue at Drayton, Trace 6262 raw water with- and without-outlet hardness concentrations were compared. The trace data showed that the with-outlet hardness was only elevated by an average of 5 mg/L over the average without-outlet concentration of approximately 250 mg/L. Based on this average increase of only 2 percent, it was assumed that the existing chemical feed equipment would be adequate to handle the increased chemical feed rates required due to outlet operations.

Drayton city staff provided the cost of lime and soda ash used in their softening process. The cost for polymer was assumed to be equal to that for Valley City, and the carbon dioxide cost was assumed to be equal to that of Grand Forks.

Sludge production data were unavailable from the city, so sludge production and cost data were assumed to be equivalent to that of Valley City on a pounds of sludge produced per pound of hardness removed basis. Sludge disposal cost data were provided by Drayton and used in model development.

The following estimates were used in the Phase I mitigation model for Drayton:

Flow, annual average (MGD)	0.25
Target finished water hardness (mg/L)	130
Pounds of lime used per pound of hardness removed	4.03
Pounds of soda ash used per pound of hardness removed	0.52
Pounds of CO ₂ used per pound of hardness removed	0.35
Pounds of polymer used per pound of hardness removed	0.0013
Pounds of sludge produced per pound of hardness removed	3.15

3.2.5.7 Modeling Assumptions for Pembina

The City of Pembina currently serves approximately 650 people, and uses the Red River of the North as its raw water source. The facility was constructed in 1970 and has a maximum capacity of 0.58 MGD. The average daily water usage is 0.17 MGD. In emergency situations, Pembina can obtain water from a rural water supplier.

In evaluating the need for capital improvements required to treat additional hardness at Pembina, Trace 6262 raw water with- and without-outlet hardness concentrations were compared. The trace data showed that the with-outlet hardness was only elevated by an average of 4 mg/L over the average without-outlet concentration of approximately 256 mg/L. Based on this average increase of less than 2 percent, it was assumed that the existing chemical feed equipment would be adequate to handle the increased chemical feed rates required due to outlet operations.

Sludge disposal information was not available from the water treatment facility personnel and was estimated from per-pound-of-hardness-removed averages obtained from other facilities. The cost of sludge disposal was estimated using data from the Drayton facility.

The following estimates were used in the Phase I mitigation model for Pembina:

Flow, annual average (MGD)	0.07
Target finished water hardness (mg/L)	120
Pounds of lime used per pound of hardness removed	2.53
Pounds of soda ash used per pound of hardness removed	0.22
Pounds of CO ₂ used per pound of hardness removed	0.43
Pounds of sludge produced per pound of hardness removed	3.15

3.2.5.8 Modeling Assumptions for Letellier

Letellier is located in Manitoba, Canada, approximately 10 miles north of the United States-Canadian border. The City of Letellier's water treatment facility is operated by a private Canadian company. Several attempts were made to obtain information from the facility staff and operator in Letellier and from the general manager of the private operating company in Altona, Manitoba, but were unsuccessful. Therefore, all Phase I modeling parameters for Letellier were estimated using data from other facilities. It is not anticipated that using estimated data at this location will significantly affect the overall mitigation cost estimates. The difference between with- and without-outlet constituent concentrations for Trace 6262 near Letellier appear to be minimal.

The Letellier treatment facility currently serves the entire surrounding county, and treatment facility staff stated that the facility's average daily finished water output is approximately 1.0 MGD. Monthly withdrawal rates from the Red River were not available as input for the mitigation model. To compensate for this data gap, annual average flow was scaled from the Pembina data, and it was assumed that the treatment processes for the two facilities were identical. The chemical feed rates and sludge production rates were also assumed to be equivalent to those for Pembina.

The following estimates were used in the Phase I mitigation model for Letellier:

Flow, annual average (MGD)	1.0
Target finished water hardness (mg/L)	120
Pounds of lime used per pound of hardness removed	2.53
Pounds of soda ash used per pound of hardness removed	0.22
Pounds of CO ₂ used per pound of hardness removed	0.43
Pounds of sludge produced per pound of hardness removed	3.15

3.2.5.9 Modeling Assumptions for Morris

The City of Morris, located in the province of Manitoba, uses raw water from the Red River to serve a population of approximately 1,700 people. The average water use reported was 0.73 MGD. Lime, soda ash, and polymer are the chemicals used in the treatment processes. Beyond this information, no other data were available at the time this report was prepared. The City of Morris water treatment facility is operated by the same private Canadian company as Letellier's and the company declined to provide any further information. Therefore, costs associated with mitigation of Devils Lake outlet operations were estimated based on the data received from other treatment facilities.

Because the average annual flows are approximately equal to those of Grafton, monthly average flow data for each month were estimated based on the Grafton data. Chemical usage and sludge production, as well as the costs associated with each, were also estimated from Grafton data.

Because no trace data were available beyond the United States-Canadian border, the raw water data from Emerson were used. Morris is approximately 12 miles downstream from the Emerson station, and there are several tributaries that flow into the Red River of the North between Emerson and Morris. Therefore, the resultant mitigation cost estimated for Morris is likely to be higher than would actually occur.

The following estimates were used in the Phase I mitigation model for Morris:

Flow, annual average (MGD)	0.73
Target finished water hardness (mg/L)*	127
Pounds of lime used per pound of hardness removed	0.98
Pounds of soda ash used per pound of hardness removed	0.26
Pounds of CO ₂ used per pound of hardness removed	0.27
Pounds of polymer used per pound of hardness removed	0.00094
Pounds of sludge produced per pound of hardness removed	3.15

^{*} Estimated from Grafton data

3.2.6 Development of Phase II Mitigation Model

As has been described, the purpose of the Phase II model was to evaluate the available options and estimate the costs associated with providing a finished water to the consumer that would be similar in the water quality parameters analyzed to that available if the Devils Lake outlet was not constructed.

Only hardness (calcium and magnesium concentrations) would be reduced by current water treatment facility processes; other water quality parameters that increase due to the outlet will not be affected by current treatment facility processes. The water quality parameters not affected by conventional treatment processes in place at the treatment facilities include the ions sulfate (SO_4^{-2}) , chloride (Cl), and sodium (Na^+) . Although the increase in the concentration of these constituents due to outlet operations will not cause them to exceed SDWA Secondary Standards in most cases, Phase II evaluates options to remove these constituents through treatment. Phase II also

investigates alternate water source options available to the treatment facilities as an option to mitigate the anticipated effects of the outlet from Devils Lake.

3.2.6.1 Development of Capital and O&M Costs for Ion Exchange

Because SO_4^{2-} , Cl^- , and Na^+ are not removed by lime-soda ash softening or the other treatment processes currently in place at the treatment facilities, ion exchange was selected as a likely treatment process to develop costs for treatment and compare treatment costs to alternative water supply options. To simplify the development of capital and additional operations and maintenance costs associated with ion exchange, it was assumed that the increase of the total dissolved solids due to the outlet could be accounted for solely by the increase of SO_4^{2-} , Cl^- , and Na^+ concentrations. Furthermore, it was assumed that by reducing TDS concentrations from with-outlet to without-outlet levels, a treated water quality similar to that of the without-outlet scenarios would result.

Ion exchange almost completely removes the ions in the water and, therefore, only a portion of the total water supplied to the users would be required to undergo ion exchange treatment. The ion-free finished water stream from the process would then be blended with the stream from the existing treatment processes. In this manner, a blended finished water could be produced that would be similar to that of the without-outlet scenarios.

Capital costs for ion exchange processes were developed using the USEPA document *Estimation of Small System Water Treatment Costs* (R.C. Gumerman, et. al., USEPA, 1984). This document gives curves for capital and O&M costs for various treatment technologies. The document focuses on treatment facility sizes ranging from 2,500 gallons per day (gpd) to 1 million gallons per day (MGD). The items included in the capital cost curves includes:

- ! Excavation and Site Work
- ! Manufactured Equipment
- ! Concrete
- ! Steel
- ! Labor
- ! Piping and Valves
- ! Electrical and Instrumentation
- ! Housing

A contingency is also included as part of the capital costs. To be able to input the capital cost curve into the mitigation model and allow for flexibility between treatment facilities and traces, a best-fit analysis was performed on the data used to develop the cost curve. The resulting equation from this line was programmed into the Phase II model.

The estimate of the size and capacity of the ion exchange unit required depends on the flow rate and the TDS concentration of the water fed to the unit. The amount of flow fed to the unit will be a fraction of the total treatment facility flow, but will be related to the overall demand at the plant. Therefore, the unit sizing and associated capital cost estimates were based on the maximum monthly water demand and the highest TDS concentration (as seen in the trace data) for that month. The estimated capital cost was updated from 1983 dollars to 1998 dollars by multiplying the result by the 1998 to 1983 ratio of the Construction Cost Index (CCI) published by Engineering News Record.

The same sources and methods were relied upon to develop the O&M costs for ion exchange. The items included in the O&M cost curves include:

- ! Energy
- ! Maintenance Material
- ! Regeneration Chemical Costs
- ! Labor

This study did not address any costs that may be associated with the disposal of the brine that results from regeneration of the ion-exchange resin. The EPA lists seven methods for disposal of brine waste in their document, *Management of Water Treatment Plant Residuals* (1996): (1) direct discharge to surface water, (2) deep well injection, (3) spray irrigation, (4) discharge to a drainfield or borehole, (5) discharge to sanitary sewer collection systems, (6) brine concentration, and (7) brine evaporation ponds. Preliminary investigations indicate that discharge to the sanitary sewer collection systems would be the least cost alternative for these water treatment facilities. NPDES permits would need to be revised for each facility to reflect the change in effluent quality. Further discussions of brine disposal options and costs will be included in the Addendum to this report.

The assumed labor cost was \$40/hour and the energy cost was assumed to be \$0.05/kw-hr. Sulfuric acid (H_2SO_4) was assumed to be used as the strong acid for regeneration. Local chemical feed suppliers give the cost of H_2SO_4 as either \$0.19/lb for 330-gallon totes or \$0.15/lb for bulk shipments (approximately 3,000 gallons). Sodium hydroxide (50 percent NaOH) was assumed to be used as the

strong base for resin regeneration. The cost of NaOH was either \$0.40/lb for 330-gallon totes or \$0.36/lb for bulk shipments (approximately 3,000 gallons).

Because the amount of TDS needed to be removed varied month to month and from facility to facility, the O&M costs were developed on a per-pound-of-TDS-removed basis for the various treatment facilities. The values were plotted and a cost curve was developed for per-pound cost for TDS removed versus treatment facility system size. A best fit analysis of the curve was performed and the resulting equation was used in the Phase II model.

The capital cost for ion exchange was assumed to be incurred in the first year of operation. Replacement frequency will depend to some extent on the demands placed on the ion exchange unit, but two replacements were assumed to be required over the course of the 48-year cost projection. Therefore, full replacement of the ion exchange systems was assumed to be required in years 16 and 32. The O&M cost was estimated using the cost equation and the monthly pounds of TDS to be removed by each facility. The costs were brought to present worth values and annualized for the 50-year modeling period. A 1998 interest rate of 7-1/8 percent was used in the economic analysis.

3.2.6.2 Development of Capital and O&M Costs for Alternative Water Supply Options

Groundwater was initially considered as the likeliest alternate source water for municipal users. To evaluate the possibility of using groundwater as an alternative municipal supply source, aquifer information was gathered separately for each State/Province. In North Dakota, this information was obtained from county groundwater studies published by the North Dakota Geological Survey and through communications with Milton Lindvig (Director of Water Appropriations for the North Dakota State Water Commission). In Minnesota, aquifer information was obtained from Designation of Principal Water-Supply Aquifers in Minnesota, published by the U.S. Geological Survey. Manitoba aquifer information was obtained through communications with Eric Carlson of Manitoba Water Resources.

Investigation of the area aquifers revealed that the only usable groundwater was contained in surficial aquifers. Deeper aquifers represented by the Dakota Group and the Montana Group are also present throughout the study region. However, these aquifers are of poor water quality and water yields are small, making them virtually useless as a drinking water source.

Surficial aquifers, having acceptable water quality but variable yields, are scattered throughout the region. Those municipalities with possible access to groundwater are discussed in later sections.

The area around Pembina, Drayton, and Grafton has virtually no surficial aquifers available on either the North Dakota or Minnesota side of the Red River of the North. As has been stated, the deep aquifers are of poor quality.

In addition to groundwater sources, other options were considered. Additional water supply options were investigated for each treatment facility to compare the cost associated with onsite treatment to that of obtaining water of better quality from an alternate source. These additional options included obtaining raw water from wells, rural water supply, or from nearby rivers not affected by the Devils Lake outlet.

The raw water quality of each alternate source was compared to the existing raw water source water quality. In most cases the hardness levels were expected to be similar to those of the raw water, and in no case were these concentrations identified as being significantly lower in the alternate supply. In cases where the alternate supply had higher hardness, it was assumed that the existing facility would treat the alternate source water down to the facility target finished hardness concentration and an increase in operations cost would result. This increase in treatment cost was included in the Phase II mitigation model. It was also assumed that no modifications or additions to the existing water treatment processes would be necessary to treat water supplied from a source other than the Sheyenne River or Red River of the North. Lime-soda ash softening was assumed to be adequate for treating the alternate raw water source in order to produce water of the quality that would be obtained if there were no outlet from Devils Lake.

In cases where wells or a rural water supply were assumed to be the alternate water supply source, capital and annual O&M costs associated with constructing wells and conveying the water from the alternate source to the treatment facility were considered. Additional treatment costs, if necessary, were calculated as discussed above.

Cost assumptions used to develop cost estimates for wells or rural water as the alternative water supply are presented in Table 3-7. A brief discussion on the assumptions used to develop cost estimates for the alternative water supply sources for each of the municipalities is given in the following paragraphs.

Valley City

The alternative water supply source for Valley City was assumed to be two wells that would totally replace the Sheyenne River as the raw water supply source. Each well would be designed to meet the maximum average monthly demand, and both wells combined would meet the maximum demand. The nearest usable aquifer to meet Valley City's water demand is the Spiritwood Aquifer. To convey the water to Valley City would require the construction of an 18-mile pipeline. (A rural water supplier in the area was contacted but did not have the capacity to serve a city the size of Valley City.)

Fargo

Fargo currently draws approximately 10 percent of its total water supply from the Sheyenne River. Fargo uses its Sheyenne River intake when the water quality of the Red River of the North is poor. It was assumed that under with-outlet conditions Fargo would need to draw water from a source other than the Sheyenne River for such periods, and that wells could replace the water currently obtained from the Sheyenne River intake. The nearest groundwater source with sufficient yield to supply Fargo is the Sheyenne Delta Aquifer situated approximately 40 to 50 miles from Fargo. Construction of the wells and a 40- to 50-mile pipeline would be required to supply Fargo with an alternate raw water source. (Area rural water suppliers are unable to meet the water demands of Fargo.)

Grand Forks

Grand Forks currently blends raw water from the Red River of the North with water from the Red Lake River prior to treatment and distribution. Approximately 40 percent of the water supply currently comes from the Red River of the North. To replace the water withdrawn from the Red River of the North, construction of two groundwater wells would be required. The wells would not be used to meet peak demands; the facility is assumed to be capable of meeting peak demands by increased withdrawals from the Red Lake River. The nearest surficial aquifer to Grand Forks is the West Larimore Aquifer, which is approximately 20 miles west of Grand Forks. Based upon discussions with the North Dakota State Water Commission, this aquifer is heavily appropriated and is not likely to be a good alternative for Grand Forks. Wells as an alternative raw water supply was not available to Grand Forks and an alternate water supply cost was not developed. (An area rural water supplier provides water to neighboring towns and to rural houses right up to the Grand Forks city limits. However, the supplier does not have the capacity to replace the amount of water drawn from the Red River of the North.)

Grafton

Grafton currently is able to withdraw water from the Park River as an alternate water supply. For this analysis, it was assumed that the Grafton facility would be able to meet its demands by withdrawing water solely from the Park River. However, the hardness levels in the Park River water are significantly greater than those of the Red River of the North. Therefore, the cost for using the Park River as an alternate supply was assumed to consist of the additional cost associated with removal of the additional hardness. Unit costs developed under Phase I for hardness removal on a per-pound basis were used to estimate this additional cost.

Another option for Grafton is to hook up to an area rural water supplier. Walsh Water Users, Inc. supplies water in the area and could serve Grafton with some additions to their distribution system. It is estimated that they would need an additional 27 miles of pipeline to serve Grafton.

Drayton

Drayton is in an area of the state with virtually no usable groundwater, so wells are not an alternative. One feasible alternate for Drayton is to hook up to rural water. North Kittson Rural Water, based out of Lake Bronson, Minnesota, has already performed a feasibility study to estimate the cost estimate for Drayton to use North Kittson Rural Water as their water supply.

Pembina

Pembina is in an area of the state with virtually no usable groundwater, so wells are not an alternative. A more feasible alternative is for Pembina to connect to rural water supplier. North Valley Water Association provides rural water in the area and already has a pipeline to Pembina.

Letellier

The alternative water supply source for Letellier was assumed to be two wells that would be constructed to totally replace the Red River of the North as the city's raw water supply source. Each well was designed to meet the maximum average monthly demand, and both wells combined would meet the maximum demand. The nearest usable aquifer is approximately 10 miles east of Letellier. This would require the construction of 10 miles of pipeline. Letellier supplies water to area towns so rural water is not an option; Letellier is in effect the rural water supplier in the area.

Morris

The alternative water supply source for Morris was assumed to be two wells that would be constructed to totally replace the Red River of the North as the city's raw water supply source. Each well was designed to meet the maximum average monthly demand, and both wells combined would meet the maximum demand. The nearest usable aquifer is a limestone aquifer approximately 13 miles east of Morris. This would require the construction of 13 miles of pipeline. (Information regarding the availability of rural water was not made available.)

3.2.6.3 Phase II Model Operation Description

On a trace-by-trace basis, the Phase II model calculates the estimated capital and O&M cost for ion exchange treatment, and calculates the capital and O&M costs for developing an alternative water supply source for each water treatment facility. The model compares the annualized cost of ion exchange treatment to the annualized cost for developing and using the alternative water supply or supplies. It then selects and presents the lowest-cost option for each water treatment facility.

3.3 Results

3.3.1 Phase I Results

Figures 4 through 16 present raw and finished water quality data for the water treatment facilities, assuming that the changes in water quality due to pumping from Devils Lake are addressed only through additional softening.

Because it was assumed that only hardness would be reduced by treatment down to current finished water hardness concentrations, the TDS remaining after softening would be attributed to residual hardness and concentrations of ions other than calcium and magnesium (i.e., chloride, sulfate, etc.). A comparison of the with-outlet raw and finished (assuming softening only) water TDS concentrations is shown on Figures 4, 7, 9, 11, 13, and 15. The without-outlet raw water concentrations are also shown on these figures to allow a visual comparison of the frequency of exceedance of the secondary TDS standards.

Without-outlet finished water TDS concentrations would be expected to be approximately equal to current finished water concentrations for the facilities. In most cases, data regarding finished water TDS concentrations was unavailable (see figure footnotes). Modeling similar to that done for the with-outlet raw water could provide estimates of future without-outlet finished water TDS concentrations, but such modeling was not a part of this study.

With-pumping finished water sodium concentrations are presented for Valley City on Figure 6. Figure 6 shows that the estimated (see Section 3.2.5 for estimation assumptions) concentrations at Valley City do not exceed the WHO sodium guideline standard of 200 mg/L at Valley City. It can therefore be inferred that sodium concentrations would not exceed the guideline at any of the treatment facilities downstream. For this reason, estimates of sodium concentrations are not shown for other than Valley City. In assessing possible sodium concentration standard exceedances, it is the finished water concentrations that are of principal concern; Figure 6 displays the "Finished Water" sodium concentrations. This designation is accurate, although the finished water and raw water concentrations are likely to be the same, because the treatment facilities do not currently employ any treatment technologies that would be expected to reduce sodium concentrations.

Despite the finished water being of primary concern, only the raw water sulfate concentrations for all of the treatment facilities are presented on Figures 5, 8, 10, 12, 14, and 16. Softening would not be expected to remove sulfate from the raw water, but the data for some of the treatment plants shows the finished water sulfate concentration being lower than the raw water concentration. However, because the finished water concentrations may vary slightly (based on limited data from the water treatment facilities) and cannot be estimated with precision, they are not shown. The raw water sulfate concentrations presented on the figures are expected to closely approximate those of the finished water, and can therefore be taken as a proxy for the finished water concentrations.

The following paragraphs discuss TDS, sodium, and sulfate concentrations (where applicable) at each of the eight treatment facilities. Note that attention is focused on Trace 6262, that trace being (of the sample traces supplied by the Corps for this study) the one having on average the greatest changes between without-outlet and with-outlet conditions.

Valley City—The predicted Trace 6262 TDS finished concentration will exceed the secondary standard of 500 mg/L about half the time.

Although the data received from the Valley City facility indicate that a slight reduction in the sulfate concentration occurs as a result of treatment, no treatment processes could account for this reduction. It was, therefore, assumed for this analysis that the Valley City facility's finished water sulfate concentration would be equal to the raw water sulfate concentration. Using this assumption, the sulfate concentration would exceed the secondary standard of 250 mg/L frequently (Figure 5). However, the proposed primary standard for sulfate of 400 mg/L would be exceeded only occasionally.

The sodium concentration was also calculated and plotted (Figure 6). The results indicate that the 200 mg/L WHO guideline for sodium would not be exceeded.

Fargo—Trace 6262's finished water TDS concentration would exceed the secondary standard of 500 mg/L nearly half of the time (Figure 7). The sulfate concentration would exceed the secondary standard of 250 mg/L approximately one-third of the time (Figure 8). However, the proposed primary standard for sulfate of 400 mg/L would be exceeded only once.

Grand Forks—Trace 6262's finished water TDS concentration would exceed the secondary standard of 500 mg/L only four times during the modeled 50-year period (Figure 9). Similarly, the sulfate concentration would exceed the secondary standard of 250 mg/L only four times (Figure 10), and the proposed primary standard of 400 mg/L would never be exceeded.

Grafton—Trace 6262's finished water TDS concentration would exceed the secondary standard only twice during the 50-year modeled period (Figure 11). The 250 mg/L secondary standard for sulfate would never be exceeded during outlet operations (Figure 12).

Drayton—Trace 6262's finished water TDS concentration would not exceed the secondary standard of 500 mg/L during outlet operations. The secondary standard for sulfate of 250 mg/L would never be exceeded during outlet operations (Figure 14).

Pembina—Trace 6262's finished water TDS concentration would not exceed the secondary standard of 500 mg/L during outlet operations. The 250 mg/L secondary standard for sulfate would never be exceeded during outlet operations (Figure 16).

Letellier—Trace 6262's finished water TDS concentration would not exceed the secondary standard of 500 mg/L during outlet operations. The 250 mg/L secondary standard for sulfate would never be exceeded during outlet operations (Figure 16).

Morris—Trace 6262's finished water TDS concentration would not exceed the secondary standard of 500 mg/L during outlet operations. The 250 mg/L secondary standard for sulfate would never be exceeded over the outlet operations (Figure 16).

Table 3-8 presents the Phase I cost estimate results. Appendix I gives the seven trace-by-trace listings of the Phase I estimated present worth and annualized costs for each of the treatment facilities.

It will be noted that although Trace 6262 was seen as the trace with the greatest change in water quality, Trace 498 results in higher overall costs in the model output. This is due to the fact that Trace 498, while having a lower overall increase in hardness concentrations, has higher monthly average increases during the first 15 years of pump operation. This results in a higher estimated present worth for Trace 498; for Trace 6262 the increased costs are incurred later in the modeled 50-year period and so result in a lower present worth.

3.3.2 Phase II Results

There are no figures presented to demonstrate Phase II results because the with-outlet monthly concentrations of total hardness, TDS, and sulfate were assumed to already have been reduced (by Phase II treatment) to their corresponding without-outlet concentrations.

Table 3-9 presents the Phase II cost estimate results. It also indicates the treatment or alternate source option that would likely result if treatment to without-outlet constituent concentrations is required. The cost-effectiveness of the Phase II treatment was not determined as part of this study. Cost justification would require a comparison of the Phase II costs to the estimated benefits of the increased treatment. Appendix J presents the seven trace-by-trace listings of the Phase II estimated present worth and annualized costs for each of the treatment facilities.

3.4 Discussion

Note that modeled mitigation costs for this study reflect only the costs that would be associated with the conservative water quality parameters output by the HEC-5/5Q model. Furthermore, the modeled costs are based on sample traces provided by the Corps for this study. The trace data are likely to change as refinements are made to the operating plan for the outlet.

The Phase I model costs reflect the increased softening that the treatment facilities would need to provide during outlet operation in order to produce the same hardness levels that would result if no outlet were constructed. TDS and sulfate finished water concentrations in the with-outlet finished water, however, surpass the secondary standard concentrations in many cases. The result of these increases may include changes in water taste and odor, as well as possible health effects for at-risk

populations. However, allowable concentrations for these constituents are governed only by secondary standards, and concentration increases due to the outlet may be acceptable to local water users.

The Phase II model costs reflect the increased costs that the treatment facilities would incur in order to provide finished water at the same concentrations of hardness, TDS and sulfate that the finished water would have if the outlet were not constructed. For most of the facilities, the construction and operation of an ion-exchange treatment system was the least expensive technology option. Wells were the least expensive technology option for Valley City, and treatment of the Park River water was the least expensive option for Grafton.

The difference in costs predicted by the Phase I model and the Phase II model are substantial. There are high costs associated with the removal of TDS by ion exchange or the development of alternative water sources. Modeling showed the total annualized cost for increased softening for the traces analyzed ranging from \$24,000 per year to \$54,000 per year, depending on the modeled water quality future. By contrast, the total annualized cost for capital improvements or alternate source water development required to bring the with-outlet finished water to the water quality of without-outlet finished water ranged from \$1,757,000 per year to \$3,304,000 per year for the traces analyzed.

Section 3 Tables

Table 3-1	Categories of Traces Selected for Downstream Water Users Analyses
Table 3-2	Maximum Contaminant Levels (MCLs) and Maximum Contaminant Level Goals (MCLGs)
Table 3-3	Municipal Water Treatment Facility Water Quality Standards, United States Regulations and Guidelines
Table 3-4	Municipal Water Treatment Facility Water Quality Standards, Canadian Guidelines
Table 3-5	Municipal Water Treatment Facility Permitted Users
Table 3-6	Municipal Water Treatment Facilities with Corresponding Trace Data Stations
Table 3-7	Municipal Water Treatment Facilities Cost Summary
Table 3-8	Phase I Additional Costs for Hardness Removal
Table 3-9	Phase II Additional Costs for Hardness Removal

Table 3-1

Categories of Traces Selected for Downstream Water Users Analyses

Category	Description	Trace	Without Outlet	With Outlet
1	Devils Lake does not spill to Stump Lake (1446.6) under natural conditions. Therefore, future damages can be mitigated at minimal cost. The outlet is not needed. Most of these traces show a moderate rise in lake level followed by a sustained decline.	10	Lake peaks at 1445.5 in 2000 and declines thereafter (versus 1446.6 spill elevation to Stump Lake).	Outlet does not affect peak, but reduces lake level by max 1½ feet thereafter.
2	Future lake level rises cause extensive damages, which occur before the outlet is operational (assumed startup May 2001). Although the outlet might result in faster drawdown of those lake levels, it is not effective in averting damages or damage prevention costs.	6	Lake reaches 1448.5 in 2002 and 1448 in 2032.	Outlet does not prevent first spill to Stump Lake, but lowers second peak to 1446, which prevents second spill.
3	The outlet can avert considerable flood damages and damage prevention costs. Because those benefits occur in the near-future,	498	Lake peaks at 1454.5 in 2008.	Outlet reduces peak to 1451.5
	their present value is high and, therefore, the project's benefit-cost ratio (measure of economic feasibility) tends to be high.	2848	Lake peaks at 1452 in 2009.	Outlet reduces peak to 1448.5; outlet reduces lake level by max of 7 feet in 2015.
4	Rapid lake level rises overwhelm the outlet's design capacity; therefore, the outlet is not effective in averting flood damages and damage prevention costs.	No trace	es in this category were a	nalyzed.
5	The outlet is very effective in lowering lake levels and, therefore, averting flood damages and damage prevention costs. However, because	6600	Lake drops initially, then rises again to 1448 peak and spill to Stump Lake in 2029.	Outlet reduces 2029 peak to 1445, which prevents spill to Stump Lake.
	those benefits occur in the distant- future, their present value is reduced and, therefore, the project's benefit- cost ratio is abated.	6262	Lake peaks twice— 1448 with spill to Stump Lake in 2003 and 1454 after 2040 with spill to Stump Lake in 2024.	Lake rises too fast for outlet to prevent either spill, although outlet delays second spill 2 years.
		7352	Lake drops initially, then rises quickly to 1460 peak and spill to Sheyenne River in 2032.	Outlet reduces peak to 1457, which prevents spill to Sheyenne River.

Maximum Contaminant Levels (MCLS) and Maximum Contaminant Level doals (MCLGS)									
CHEMICAL NAME	CAS	MCL	Proposed MCL	MCL	MCL	MCL Goal	MCL Goal	MCL Goal	
OHEMIOAE NAME	#	ug/L.*	ug/L *	Comments	Comments Source u		Source	Comments	
Acifluorfen	5094666			·			SDW Hotline	O, tentative	
Acrylamide	79061		•	trealment technique	40CFR141.61	o	40CFR141.50		
Acrylonitrile	107131	·					SDW Hotline	0, tentative	
Alachior	15972608	2			40CFR141.61	0	40CFR141.50		
Aldicarb	116063	3		postponed;new drft rule has 7 ug/l for sum of 3 aldicarb compds	40CFR141.61	1	40CFR141.50	postponed;new draft rule has 7 ug/L as sum of 3 aldicarb compds	
Aldicarb sulfone	164 6884	2		postponed;new draft rule has 7 ug/l for sum of 3 aldicarb compds	40CFR141.61	1	40CFR141.50	postponed;new draft rule has 7 ug/L as sum of 3 aldicarb compds	
Aldicarb sulfoxide	1646873	4		postponed;new draft rule has 7 ug/l for sum of 3 aldicarb compds	40CFR141.61	1	40CFR141.50	postponed;new draft rule has 7 ug/L as sum of 3 aldicarb compds	
Antimony	7440360	6		·	40CFR141.62	6	40CFR141.51		
Arsenic	7440382	50		Interim; under evaluation; EPA req. to regulate by 1/1/2001	40CFR141.11		40CFR141.51		
Asbestos	1332214	700000 0		fibers > 10 um/L	40CFR141.62	7000000	40CFR141.51	fibers > 10 um/L	
Atrazine	1912249	3			40CFR141.61	3	40CFR141.50		
Barlum	7440393	200 0			40CFR141.62	2000	40CFR141.51	i ·	
Bentazon	25057890						SDW Hotline	20, tentative	
Benzene	71432	5		·	40CFR141.61	О	40CFR141.50		
Benzo(a)anthracene	5 6553			Previously proposed at 0.1 - no longer proposed	55FR30370		55FR30370		
Benzo(a)pyrene	5 0328	.2			40CFR141.61	0	40CFR141.50		
Benzo(b)fluoranthene	20 5992			Previously proposed at 0.2 - no longer proposed	55FR30370		55FR30370		
Benzo(k)fluoranthene	207089			Previously proposed at 0.2 - no longer proposed	55FR30370		55FR30370		
Beryllium	7440417	4			40CFR141.62	4	40CFR141.51		
Beta particle and photon emitters	8052	4	4	mrem ede/yr(excl. Ra-228); proposed at 4 from manmade sources; see regs	40CFR141.16; prop. 56FR33050		56FR33050	Interim final; proposed at 0 mrem ede/yr excluding Ra-228; see regs	
gamma-BHC	58899	.2		·	40CFR141.61	.2	40CFR141.50		
Bis(2-ethylhexyl) adipate	103231	40 0	·		40CFR141.61	1	40CFR141.50		
Bis(2-ethylhexyl) phthalate	117817	6		_	40CFR141.61	0	40CFR141.50		
Bromate	14		10		59FR38668		59FR38668	0, proposed	
Bromoacetic acid	79083		60	Proposed MCL is for sum of 5 haloacetic acids	59FR38668			-,	
		· · · · · · · · · · · · · · · · · · ·					14.4	<u></u>	

^{*} Units in ug/L unless noted.

*CL; - Maximum Contaminant Level. Maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

*MCLG - Maximum Contaminant Level Goal. A non-enforceable concentration of a drinking water contaminant that is protective of adverse human health effects and allows an adequate margin of safety.

*SDW Hotline - Safe Drinking Water Hotline (800) 426-4791

Tentative values have not been officially proposed.

*Discrept CAS #'s less than 50000 - for data management, purposes only.

CHEMICAL NAME	CAS	MCL	Proposed MCL	MCL	MCL	MCL Goal	MCL Goal	MCL Goal
3.12.113.12.11	#	ug/L *	ug/L *	Comments	Source ug/L •		Source	Comments
Bromodichloromethane	75274	100	80	MCL is for sum of trihalomethanes	40CFR141.12; Pr.MCL 59FR38668		59FR38668	0, proposed
Bromoform	75252	100	80	MCL is for sum of trihalomethanes	40CFR141.12; Pr. MCL 58FR38668		59FR38668	0, proposed
Butyl benzyl phthalate	85687			Prev. proposed with Phase V rule at 0. 1; no longer proposed	55FR30370; 57FR31791		55FR30370	verify that no longer proposed at 0
Cadmium	7440439	5			40CFR141.62	5	40CFR141.51	
Carbofuran	1563662	40			40CFR141.61	40	40CFR141.50	
Carbon tetrachloride	56235	5		·	40CFR141.61	0	40CFR141.50	1
Chloral hydrate	302170		60	If 60 for total of 5 haloacetic acids is met, chloral hydrate is considered acceptable; see regs	59FR38670		59FR38668	40, proposed
Chlordane	57749	2			40CFR141.61	О	40CFR141.50	l ,
Chlorine	7782505		4000	Maximum Residual Disinfectant Level (MRDL) as Cl2	59FR38668		59FR38668	4000, proposed, MRDLG as Cl2
Chlorine dioxide	10049044		800	Maximum Residual Disinfectant Level (MRDL) as Cl2	59FR38668		59FR38668	300, proposéd/tentative, MRDLG as CI2
Chlorite	14992277		1000	· ·	59FR38668		59FR38668	80, proposed
Chloroacetic acid	79118		60	Proposed MCL is for sum of 5 haloacetic acids	59FR38668		. tus	
Chloramine	59		4000	Maximum Residual Disinfectant Level (MRDL) as Cl2	59FR38668		59FR38668	4000, proposed, MRDLG as Cl2
Chlorobenzene	108 907	1 0 0		_	40CFR141.61	100	40CFR141.50	
Chloroform	67 663	10 0	80	MCL is for sum of trihalomethanes	40CFR141.12; Pr.MCL 59FR38668		59FR38668	0, proposed
Chromium	7440 473	10 0			40CFR141.62	100	40CFR141.51	
Chrysene	218 019			Previously proposed at 0.2 - no longer proposed	55FR30370		55FR30370	
Copper	7440508	130 0		action level/tap; treat. technol.	40CFR141.80	1300	40CFR141.51	
Cryptosporldum	75	į	·	monitoring required under information Collection rule, future reg. likely	40CFR141.43			
Cyanazine	21725462					,		1, tentative
Cyanide	57125 ·	200	1	free cyanide	40CFR141.62	200	40CFR141.51	

MCL1

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SDW Hotline - Safe Drinking Water Hotline (800) 426-4791

Tentalive values have not been officially proposed.

CHEMICAL NAME	CAS	MCL	Proposed MCL	MCL	MCL	MCL Goal	MCL Goal	MCL Goal
OHEMIOAL WANE	#.	ug/L *	ug/L *	Comments	Source	ug/L *	Source	Comments
2,4-D	94757	70			40CFR141.61	70	40CFR141.50	
Dalapon	75990	200			40CFR141.61	200	40CFR141.50	1
Dibenzo(a,h)anthracene	5 3703			Previously proposed at 0.2 - no longer proposed	55FR30370		55FR30370	
Dibromoacetic acid	15		60	Proposed MCL is for sum of 5 haloacetic acids	59FR38668			
Dibromochloromethane	12 4481	10 0	80	MCL is for sum of trihalomethanes	40CFR141.12; Pr.MCL 59FR38668		59FR38668 ·	60, proposed
Dibromochloropropane	96128	.2			40CFR141.61	o	40CFR141.50)
Dichloroacetic acid	79436		60	Proposed MCL is for sum of 5 haloacetic acids	59FR38668		59FR38668	0, proposed
1,2-Dichlorobenzene	95501	600			40CFR141.61	600	40CFR141.50	
1,3-Dichlorobenzene	541731			Use values based on 1,2- Dichlorobenzene	SDW Hotline			
1,4-Dichlorobenzene	106467	75			40CFR141.61	75	40CFR141.50	,
1,2-Dichloroethane	107062	5			40CFR141.61	o	40CFR141.50	1 ,
1,1-Dichloroethene	75354	7			40CFR141.61	7	40CFR141.50	
cis-1,2-Dichloroethene	156 592	7 0			40CFR141.61	70	40CFR141.50	1
trans-1,2-Dichloroethene	156 605	10 0		·	40CFR141.61	100	40CFR141,50	
1,2-Dichloropropane	78 875	5		. '	40CFR141.61	o	40CFR141.50	1
1,3-Dichloropropene	542 756				·			O, tentative
Dinoseb	88 857	7			40CFR141.61	7	40CFR141.50	4.
Diquat	85 007	20			40CFR141.61	20	40CFR141.50	
Endothall	145 733	10 0			40CFR141.61	100	40CFR141.50	
Endrin	72 208	2			40CFR141.61	2	40CFR141.50	
Epichlorohydrin	106 898			treatment technique	40CFR141.61	0	40CFR141.50	
Ethylbenzene	100 414	70 0			40CFR141.61	700	40CFR141.50	
Ethylene dibromide	106 934	.0 5			40CFR141.61	o	40CFR141.50	ii.
Fecal coliform bacteria	1 152			Monitoring required by Information Collection rule, addi. regs. possible	40CFR141.143			
Fluoride	16984 488	400 0		interim; under review;fini act dela	40CFR141.62	4000	40CFR141.51	
Glardia lambia	77			treatment technique; monitoring required by Information Collection rule, addi. reg. possible	40CFR141.143	0	40CFR141.52	

^{*} Units in ug/L unless noted.

*Units in ug/L unless noted.

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*SDW Hotline - Safe Drinking Water Hotline (800) 426-4791

*Tentalive values have not been officially proposed.

Contaminant Level CAS the less than 50000 for data management, purposes only.

Disregard CAS #'s less than 50000 - for data management purposes only.

		iaximum ou	Italiilialit Lev	eis (MCLS) and Maximum Cont	arminant Lover	GOGIS (INOL	-40)	Page 4
CHEMICAL NAME	CAS	MCL	Proposed MCL	MCL	MCL	MCL Goal	MCL Goal	MCL Goal
OHENIOAL NAME	#	ug/L *	ug/L *	Comments	Comments Source u		Source	Comments
Glyphosate	1071836	700			40CFR141.61	700	40CFR141.50	
Gross alpha particle	8051	15	15	incl. radium-226, excl. radon & uranium; pCl/L; interim? final; prop. excl Ra-226, U, radon-see regs	40CFR141.15; 56FR33050; '96 Am		56FR33056	0, proposed, pCl/L; see regs
Haloacetic acids	16		60	PMCL of 30 for subpart H systems	59FR38668			
Heptachlor	76448	.4			40CFR141.61	0	40CFR141.50	· ·
Heptachior epoxide	1024573	.2			40CFR141.61	0	40CFR141.50	·
Hexachlorobenzene	118741	. 1			40CFR141.61	o	40CFR141.50	
Hexachlorobuladiene	87683							0, tentative
Hexachlorocyclopentadiene	77474	50			40CFR141.61	50	40CFR141.50	
Hypochlorite (sodium sait)	7790 923		4000	as CL2	59FR38668		SDW Hotline	4000, proposed as CL2
Hypochlorous acid	768152 9		4000	as CL2	59FR38668		SDW Hotline	4000, proposed as CL2
Indeno(1,2,3-cd)pyrene	193 395			Previously proposed at 0.4 - no longer proposed	55FR30370		55FR30370	
Lead	7439 921	,15		action level/tap;treat. technol.	40CFR141.80	0	40CFR141.51	
Legionella	81			treatment technique		o	40CFR141.52	
Mercury	7439 976	2		inorganic	40CFR141.62	2	40CFR141.51	Inorganic
Methoxychlor	72 435	40			40CFR141.61	40	40CFR141.50	
Methylene chloride	75 092	5			40CFR141.61	0	40CFR141.50	
Nickel	7440 020			Remanded 6/29/95 (100 was taken off the books); monitoring still required	40CFR141.62; 60FR33926		40CFR141.51; 60FR33926	Remanded 6/29/95 (100 was taked off the books)
Nitrate	14797 558	10000		as Nitrogen	40CFR141.62	10000	40CFR141.51	as Nitrogen
Nitrate+Nitrite	1005	10000		as Nitrogen	40CFR141.62	10000	40CFR141.51	as Nitrogen
Nitrite	14797 650	1000		as Nitrogen	40CFR141.62	1000	40CFR141.51	as Nitrogen
Oxamyl	23135 220	200			40CFR141.61	200	40CFR141.50	
Pentachlorophenol	87 865	1			40CFR141.61	0	40CFR141.50	
Picloram	1918 021	500			40CFR141.61	500	40CFR141.50	
Polychlorinated biphenyls	1336 363	.5	·		40CFR141.61	0	40CFR141.50	
Radium 226	13982 633	5	20	pCI/L; see regs; (current for R226 + R228); proposed is separate	40CFR141.15; prop. 56FR33050		56FR33050	pCI/L; see regs; proposed at zero
Radium 228	15262 201	5	20	pCI/L; see regs; (current for R226 + R228); proposed is separate	40CFR141.15; prop. 56FR33050		56FR33050	pCI/L; see regs; proposed at zero

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SDW Hotline - Safe Drinking Water Hotline (800) 426-4791

Tentative values have not been officially proposed.

OUTUON NAME	CAS	MCL	Proposed MCL	MCL	MCL	MCL Goal	MCL Goal	MCL Goal
CHEMICAL NAME	#	ug/L *	ug/L *	Comments	1		Source	Comments
Radon	10043922			proposed was 300 pC/L; Congress req. radon risk assessment; decide if reg. by Aug '99	56FR33050; see '96 SDWA ammend		56FR33050	pCI/L; see regs; proposed at zero for Radon-222; Congress delayed
Selenium	7782492	50			40CFR141.62	50	40CFR141.51	
Simazine	122349	4		٠	40CFR141.61	4	40CFR141.50	
Standard plate count	86			treatment technique			check	
Styrene	100425	100			40CFR141.61	100	40CFR141.50	
Sulfate	14808798		500	proposed but deferred;EPA required to evaluate and may regulate	59FR65578		59FR65578	500, proposed but deferred
2,3,7,8-TCDD	1746016	.00003		·	40CFR141.61	o	40CFR141.50	
Tetrachloroethene	127184	. 5			40CFR141.61	o	40CFR141.50	
Thallium	7440280	2			40CFR141.62	.5	40CFR141.51	
Toluene	108883	1000			40CFR141.61	1000	40CFR141.50	, , , , ,
Total coliforms	1165			contact SDW Hotline; monitoring required by information Collection rule	40CFR141.143	o	40CFR141.52	
Toxaphene	8001352	. 3			40CFR141.61	o	40CFR141,50	
2,4,5-TP	93721	5 0			40CFR141.61	50	40CFR141.50	٠.
Trichloroacetic acid	76039	·	60	Proposed MCL is for sum of 5 haloacetic acids	59FR38668		59FR38668	300, proposed; SDW Hotline
1,2,4-Trichlorobenzene	120821	7 0		,	40CFR141.61	70	40CFR141:50	
1,1,1-Trichloroethane	71556	20 0			40CFR141.61	200	40CFR141.50	
1,1,2-Trichloroethane	79005	5			40CFR141.61	3	40CFR141.50	,
Trichloroethene	79016	5			40CFR141.61	0	40CFR141.50	*
Trihalomethanes	1432	10 0	80	MCL is for sum of trihalomethanes; see 40 subpart H	40CFR141.12; Pr.MCL 59FR38668			
Turbidity	1155			performance standard 0.5 NTU - 1.0 NTU; check the regs	SDW Hotline; 40CFR141.13			
Uranlum	7440 611		20	20 ug/L (30 pCl/L); (see regs)	56FR33050		56FR33050	proposed at 0; (see regs)
Vinyl chloride	75 014	2		·	40CFR141.61	o	40CFR141.50	
Viruses	89			treatment technique; monitoring required under information Collection rule, future reg. possible	40CFR141.143	o	40CFR141.52	
Xylenes	1330 207	10000		idio, idiota tay, possible	40CFR141.61	10000	40CFR141.50	

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^{*}Units in ug/L unless noted.

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*SDW Hotline - Safe Drinking Water Hotline (800) 426-4791

Table 3-3

Municipal Water Treatment Facility Water Quality Standards

United States Regulations and Guidelines

Constituent		Comments
Total Dissolved Solids (TDS)	500 mg/L	Secondary Standard
Chloride	250 mg/L	Secondary Standard
Sulfate	250 mg/L	Secondary Standard
Sodium	20 mg/L	U.S. EPA Guideline
	200 mg/L	WHO Guideline

Table 3-4

Municipal Water Treatment Facility Water Quality Standards

Canadian Guidelines

Constituent		Comments
Total Dissolved Solids (TDS)	500 mg/L	Aesthetic Objective
Chloride	<250 mg/L	Maximum Acceptable Concentration
Sulfate	500 mg/L	Maximum Acceptable Concentration
	<150	Aesthetic Objective
Total Hardness	80-100 mg/L	Acceptable Level

Municipal Water Treatment Facility Permitted Users

Table 3-5

City	Permit Number	Basin	Permit Status	Comments
Drayton, ND	01244	Red River	Perfected	
	00669	Red River	Perfected	Currently uses Red River
Fargo, ND	00749	Red River	Conditionally approved	Red River Intake is upstream of Sheyenne River confluence.
	01091	Sheyenne River	Perfected	Sheyenne River serves as an alternate water source.
	04718	Sheyenne River	Held in Abeyance	
Grafton, ND	00893	Red River	NA	Currently uses Red River
Grand Forks, ND	00835	Red River	Perfected	
	00835A	Red River	Perfected	
	04354	Red River	Perfected	Currently uses Red River
Letellier, Manitoba	NA	Red River	NA	Currently uses Red River
Lisbon, ND*	03588	Sheyenne	Conditionally approved	Currently uses three 65-ft wells, no intention of using Sheyenne even if existing wells become unstable.
McVille, ND*	01151P	Sheyenne River	Perfected	Currently uses two 150-ft wells, no intake on river or treatment facility.
Morris, Manitoba	NA	Red River	NA	Currently uses Red River
Oslo, MN*	580029	Red River	NA	Terminated intake, reconnected to Marshall Polk rural system.
Pembina, ND	04054	Red River	Perfected	Currently uses Red River
Selkirk, Manitoba*	NA	Red River	NA	Currently uses well water, no intake on river.
Valley City, ND	01096	Sheyenne River	Perfected	Currently uses Sheyenne River
West Fargo, ND*	00921B	Red River	Perfected	Has no future plans to use river water, but holds permit in case wells go dry.

Notes:

Treatment facilities for the locality names marked with an asterisk were not analyzed in the present study.

Conditionally Approved: The permit holder has permission to develop their project within conditions set forth.

Perfected: The permit has been developed according to the parameters of the conditional permit and has been inspected to insure the project compliance with North Dakota Century Code.

Held in Abeyance: All or a portion of the permit is being held up pending additional information. It is neither approved nor denied but is awaitin further action.

Other municipalities that were examined as potential river water users were Winnipeg, East Grand Forks, and St. John Baptiste. None of these municipalities use river water as a source for their water treatment facilities.

Table 3-6

Municipal Water Treatment Facilities with Corresponding Trace Data Stations

Drinking Water Treatment Facility	HEC-5/5Q Trace Data Station		
Valley City	Valley City		
Fargo	Kindred		
Grand Forks	Halstad*		
Grafton	Oslo		
Drayton	Drayton		
Pembina	Emerson		
Letellier	Emerson		
Morris	Emerson		

^{*} The water quality data for the station at Halstad, rather than that of the Grand Forks station, was used for the Grand Forks drinking water facility because the facility's intake is upstream of the confluence of the Red Lake River and Red River of the North. The HEC-5/5Q station at Grand Forks is downstream of this confluence.

Table 3-7 **Municipal Water Treatment Facilities Alternate Source Summary**

	Α	Iternate Sourc	e				
Municipal Permitted User	Number of Wells	Capacity of Each Well (gpm)	Rural Water Supply	Pipeline Length (miles)	Capital Costs	Annual Operation Costs	Maintenance Costs
Valley City	2	800	NA	18	\$5,702,000	\$24,500	\$30,000/ten years
Fargo	10	750	NA	50	\$23,130,00 0	\$35,200	\$30,000/five years
Grand Forks1	NA	NA	NA	NA	NA	NA	NA
Grafton2	NA	NA	Yes	27	\$5,955,000	\$945,400	\$10,000/ten years
Drayton	NA	NA	Yes	Unknow n	\$2,442,000	\$88,000	None
Pembina	NA	NA	Yes	Unknow n	\$800,000	\$40,500	None
Morris	2	300	NA	13	\$3,056,000	\$19,700	\$4,000/ten years
Letellier	2	800	NA	10	\$3,393,000	\$19,500	\$30,000/ten years

Notes:

- Rural water and/or wells are not available for Grand Forks
 Grafton has the capability to withdraw raw water from the Park River

NA - Not Applicable, or Not Available as an alternate water source

Table 3-8
Phase I Additional Costs for Hardness Removal With-Outlet

Drinking Water Treatment Facility	1998 Dollars, Costs Annualized over 50 Years TRACE NUMBER							
	6	10	498	2848	6262	6600	7352	Average
Valley City	\$9,508	\$9,388	\$13,661	· \$11,773	\$12,564	\$7,737	\$9,280	\$10,559
Fargo	\$4,637	\$4,319	\$6,564	\$6,172	\$6,239	\$3,727	\$4,526	\$5,169
Grand Forks	\$17,795	\$12,704	\$30,199	\$28,205	\$23,635	\$11,238	\$16,191	\$19,995
Grafton	\$1,015	\$502	\$1,480	\$1,501	\$1,205	\$469	\$743	\$988
Drayton	\$607	\$334	\$910	\$945	\$716	\$328	\$521	\$623
Pembina	\$93	\$50	\$159	\$164	\$107	\$50	\$80	\$101
Letellier	\$779	\$474	\$1,317	\$1,326	\$892	\$360	\$646	\$828
Morris	\$1,542	\$903	\$1,985	\$2,171	\$1,540	\$820	\$1,058	\$1,431
Total	\$35,978	\$28,675	\$56,275	\$52,258	\$46,898	\$24,729	\$33,043	\$39,694

Table 3-9
Phase II Additional Costs for Treatment to Without-Outlet Levels

Drinking Water Treatment Facility		1998 Dollars, Costs Annualized over 50 Years TRACE NUMBER							Least Expensive Technology	
	6	10	498	28 48	6262	6600	7352	Average	to Reach Water Quality Objective*	
Valley City	\$407,807	\$407,807	\$407,807	\$407,807	\$407,807	\$407,807	\$407,807	\$407,807	Well	
Fargo	\$632,155	\$568,8 01	\$835,865	\$772,897	\$809,549	\$496,433	\$585,858		Ion Exchange	
Grand Forks	\$956,963	\$689,124	\$1,547,586	\$1,436,334	\$1,269,477	\$618,807		\$1.056.684	Ion Exchange	
Grafton	\$39,448	\$39,044		\$39,022	\$39,459	\$39,392	\$39,128	\$39,341	Treatment of Park River	
Drayton	\$39,341	\$25,587	\$50,685	\$54,168	\$42,879	\$23,601	\$33,874	\$38,591	Ion Exchange	
Pembina	\$19,290	\$14,464	\$24,494	\$25,272	\$21,519	\$13,680	\$17,602	\$19,475	Ion Exchange	
_etellier	\$126,249	\$78,343	\$173,903	\$182,170	\$145,743	\$69,047	\$106,978	\$126,062	Ion Exchange	
Morris	\$158,890	\$98,023	\$223,746	\$233,733	\$186,769	\$88,227	\$137,594	\$160,997	Ion Exchange	

^{*}Notes: Ion Exchange refers to the treatment of the existing water source to without-outlet concentrations of total hardness and TDS.

Well refers to the installation of groundwater wells and the treatment of the water, if appropriate, to without-outlet concentrations of total hardness and TDS.

Rural Water refers to the connection to the rural water system and the treatment of the water, if appropriate, to without-outlet concentrations of total hardness and TDS.

Treatment of Park River refers to using the Park River as the primary water source and the treatment of the water to without-outlet concentrations of total hardness and TDS.

The water quality objective is to treat the water source to without-outlet concentrations of total hardness and TDS.

4.1 Purpose and Scope

The purpose of this portion of the study was first to identify permitted industrial users who may be affected by changes in river water quality caused by Devils Lake outlet operations. Second, cost estimates were to be prepared for the increased expenses likely to be incurred for potentially affected industrial users under Trace 6262 conditions.

4.2 Methodology

4.2.1 Industrial Users Identification and Investigation

In order to identify the industries that may be affected by the operation of the outlet, permitted industrial users along the Sheyenne River and Red River of the North were identified and sorted by reach. The agencies responsible for permitting were contacted: North Dakota State Water Commission, Minnesota Department of Natural Resources, and Manitoba Water Resources. A listing of the industrial water-use permittees was obtained from each of the three agencies for the portions of the rivers that could potentially be impacted by outlet operations. A list of all permittees using the two rivers (sorted by country and state) is presented in Appendix D.

After sorting out permittees holding multiple permits and permit holders reported by both North Dakota and Minnesota, 11 industries remained having permits to draw from the Sheyenne River or Red River of the North in the study region. In an early phase of this study, four of the industrial users were contacted to evaluate the extent of possible impacts of Devils Lake pumping on their operations. Summaries from these initial contacts are given in Appendix F.

To gain more complete information as the study proceeded, holders of all of the eleven industrial permits were contacted and interviewed to determine the types of use and to identify the industrial facility processes. The permitted users were interviewed to determine what processes at the facility use river water, the facility's water quality requirements, what treatment (if any) is presently required to use the river water, and the potential effects of with-outlet water quality on the industrial users.

Using the interview data, the industrial users were sorted according to which might potentially be affected by Devils Lake outlet operations. Those potentially affected were interviewed further to evaluate the likely effects. If necessary, a cost estimate was prepared to give the likely mitigation cost for each potentially affected user. Trace 6262 data were used in all industrial user cost evaluations.

4.2.2 Use of Preliminary Results

Based on interview data, most of the industrial users will not be affected by outlet operations:

- ! Five of the industrial permit holders do not currently use river water. Four of these permit holders have no plans to use the river in the future. The fifth may use the river to wash rocks in the future, but would not be affected by an increased hardness.
- ! Two permittees currently use the river water to wash sand and gravel, and would not be affected by a change in water quality.
- ! Another permit holder is a ski area that uses the river water to make snow. The ski area does not treat the water and believes the increased hardness would not adversely affect their snow-making. The impact on the grass in the ski area when the snow melts was not addressed, although grasses are relatively tolerant of TDS as described in Section 5.2.4.2.

The three remaining permit holders include a paper mill, a sugar beet processing facility, and a coal-fired power plant. Uses and potential impacts are described below.

The paper mill uses the river water as part of their paper processing. The paper mill's chemist indicated that with-outlet water quality would not affect their current production of non-white paper. The paper mill has considered purchasing additional machinery to produce white paper, but it is not known if, or when, they will purchase the machinery necessary. If they were to begin making white paper, the chemist thought that an increased dissolved solids concentration might affect the process, but could not say with any certainty. Because it is not known if the paper mill is going to purchase the machinery to produce white paper and what the effect would be, mitigation cost estimates were not prepared for the paper mill for this study.

The two remaining permittees would potentially be affected by with-outlet water quality:

- ! A sugar beet processing facility on the Red River on the North uses the water to supplement their process water. The process water is treated for hardness, so the with-outlet water quality would result in increased hardness removal.
- ! A coal-fired power plant on the Red River of the North uses river water mainly as once-through cooling water and to transport fly ash. However, a small amount (less than one percent) is treated for hardness and used for boiler feed pump cooling and occasionally for boiler water makeup.

4.2.3 Development of Mitigation Model

4.2.3.1 General Considerations

To develop costs for mitigation due to outlet operation for the industrial users, a variation of the Phase I and Phase II mitigation model discussed in Section 3 was used. Because the beet processing facility treated the river water through lime softening for hardness removal, the Phase I mitigation model could be used to estimate the increase in operating cost for additional softening.

The power generating facility treated river water for TDS removal by means of an ion-exchange treatment system. Since the facility did not provide any existing operating cost data, the Phase II model was used to estimate the additional cost for TDS removal by ion-exchange treatment. No increases in capital costs were considered, because the facility currently operates an ion-exchange treatment system.

4.2.3.2 Modeling Assumptions for Sugar Beet Processing Facility

The sugar beet processing facility declined to provide detailed process information, stating that water usage is an integral part of their process and they did not want to reveal trade secrets. They did not provide the amount of river water they treat for hardness, but they did say that they withdraw water from the river in the fall (September, October, and November) and store it for year-round use in an onsite storage basin. Their monthly water usage for the last 10 years was obtained from the North Dakota State Water Commission. Because they did not provide the amount of river water that they treat, it was assumed that they treat all of the water taken from the river.

The facility did indicate that they treat for hardness with lime. The with-outlet cost was therefore estimated based upon additional softening with lime (as in Phase I of the municipal water treatment facilities model) for Trace 6262. The values for increased hardness were those for the

months (September, October, and November) that the facility withdraws water from the river, using the facility's 10-year average flow for each month. Water use, and therefore softening of the supply water stored in the onsite basin, was assumed to occur throughout the year. All costs brought back to present worth and then annualized, as with Phase I.

4.2.3.3 Modeling Assumptions for Power Plant

The power plant declined to provide detailed information about the amount of river water they use. However, they did provide the size of their pumps and a flow diagram showing the relative percentage of water they treat. The majority of their water is not treated and is used only as cooling water. However, a small portion of the water withdrawn is demineralized and used for boiler make-up water. Ion exchange is currently used for demineralization. It was assumed that the power plant would be upgraded periodically and remain operational for the 50-year project life and that water needs and treatment requirements would remain unchanged.

Based upon the capacity of their pumps and the percent treated, it was estimated that they treat 195,000 gallons per day (gpd). Cost estimates were made for extra costs incurred to remove the increase in hardness and total dissolved solids. The O&M cost equation developed under Phase II of the municipal water treatment facilities model was used with the Trace 6262 water quality data. All costs were brought back to present worth and then annualized, as with Phase II.

4.3 Results

4.3.1 Concerns of Industrial Users

In addition to the water quality changes addressed through the cost estimating described in Section 4.4, several of the industries interviewed expressed other concerns about with-outlet water. The manager of a quarry indicated that although with-outlet water quality would not affect their operation (aggregate washing), he was worried that an increase in water quantity might cause the riverbanks to erode further and the river to jump the banks more often.

As was mentioned, the paper mill indicated that if they decide to produce white paper, an increase in total dissolved solids might result in a decrease in paper quality. The sugar beet processing facility mentioned that a rapid decrease in water quality might require them to modify their treatment process. The power plant is concerned because decant water from the ash lagoon and water used for boiler feed make-up is discharged untreated to the river. They have never needed to

treat the water, but it was suggested that a decrease in source water quality might require them to treat their discharge water to meet effluent requirements.

4.3.2 Potential Effects on Industrial Users

Based upon the interviews, it was determined that only two facilities were likely to require mitigation, the sugar beet processing facility and the power plant.

To prevent mineral deposition in process equipment, the sugar beet processing facility would require additional hardness removal using lime softening. Using Trace 6262 water quality data, the estimated total present worth increased cost for hardness removal is \$16,600. The cost annualized over 50 years is \$1,200 per year.

To prevent scaling in their boilers, the power plant would incur a cost for additional removal of hardness and total dissolved solids using ion exchange. Using Trace 6262 data, the total present worth cost for additional treatment was estimated at \$416,700. The cost annualized over 50 years is \$30,700 per year. Table 4-1 summarizes the projected cost impacts for the two potentially affected industrial users, based on Trace 6262 data.

4.4 Discussion

The 11 permitted industrial users include:

- ! Five industrial permittees that do not currently use the river
- ! Two industrial facilities that use the river water to wash aggregate
- ! A ski area that uses the river water to make snow
- ! A paper mill that uses the river water as part of their paper-making process
- ! A sugar beet processing that facility uses river water to supplement the process water
- ! A power plant that uses the river water as once through cooling water, to transport fly ash, and as boiler make-up.

The only industrial users likely to incur increased costs as a result of river water quality changes were the sugar beet processing facility and the power plant. The cost estimates made for these two industrial users are based on many assumptions regarding the facilities' processes and treatment needs.

It should also be kept in mind that the costs presented in Table 4-1 for these users are based on Trace 6262. This trace data is likely to change as the operation plan for the outlet is refined.

Section 4 Tables

Table 4-1 Industrial Water Treatment Facility Cost Impacts, Trace 6262

Industrial Water Treatment Facility
Cost Impacts

Table 4-1

Trace 6262

Industrial Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars, Annualized over 50 Years)			
Coal-fired Power Plant	\$416,700	\$30,700			
Sugar Beet Processing Facility	\$16,600	\$1,200			
Total	\$433,300	\$31,900			

5.0 Other Permitted (Untreated) River Water Users

5.1 Purpose and Scope

This section of the report is concerned with river water use by permitted users (other than municipal treatment facilities and industrial users) along the Sheyenne River and Red River of the North. The purpose for investigating this permitted river water use is to evaluate the impacts that a change in water quality would have on such users. Only the permitted users located downstream of the proposed Devils Lake outlet were considered for this investigation.

After identifying the permittees, approximately 20 percent of the permitted users were interviewed to determine the types and frequency of use, and the potential effects of the with-outlet river water quality. In addition, the intake locations for the permitted river water users were identified relative to river mile location and river reach.

The potential effects on these permitted users of river water were examined through contacts with local agencies and research on each type of use. Based on the type of use, the extent of potential impacts was estimated. Water supply alternatives were investigated for the potentially affected uses.

5.2 Methodology

5.2.1 Identification of Users

A listing of the permitted users in Minnesota, North Dakota, and Manitoba was obtained from the permitting agencies: North Dakota State Water Commission (NDSWC), Minnesota Department of Natural Resources (MDNR), and Manitoba Water Resources. In North Dakota, a water-use permit is required for any water user irrigating more than one acre, or withdrawing more than 12.5 acrefeet of water per year (approximately 11,000 gallons per day) from the river. Minnesota requires a water-use permit if the daily water withdrawal is more than 10,000 gallons per day, or for domestic use serving more than 25 people. Manitoba requires a water-use permit for any users withdrawing more than 5,000 imperial gallons per day (approximately 6,000 U.S. gallons per day).

North Dakota listed 194 permittees along the Sheyenne River and Red River of the North, Minnesota listed 313 permittees along the Red River of the North, and Manitoba listed 80

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permittees along the Red River of the North. These lists of permittees included water users along both of the entire rivers, and therefore, required screening to remove from the list all permittees that are not located along the affected reaches. The Minnesota list included all water-use permittees from all sources, including groundwater, lake, stream/river, ditch, dug pit, quarry/gravel pit, and wetland. The Minnesota list was, therefore, filtered to include only those permittees who were identified as stream/river users and showed the Red River of the North as their water source. This reduced the number of Minnesota permittees from 313 to 35.

These three lists were compiled in a single database to allow sorting and to facilitate printing and generation of sublists. Sorting allowed the elimination of duplicate entries and municipal treatment facilities. Other listed permittees were removed from the database when mapping showed that they were actually on tributaries to the Sheyenne River or Red River of the North, or were on reaches unaffected by the proposed outlet. After eliminating municipal, industrial, duplicate entries, and those not on the Red River of the North and Sheyenne reaches of concern, a total of 201 permittees remained. A listing of the permittees, sorted by reach between trace data stations, is presented in Appendix C. More complete database information for the permittees of river water, sorted by country and state, is provided in Appendix D.

5.2.2 Identification by Reach

For this investigation, permittees were to be identified by river reach between trace data stations (described in Section 3.2.2). Figure 1 shows the reaches identified. The starting location for measuring the river mile locations in Manitoba was Lake Winnipeg (river mile 0.00), with the intersection with the border between the United States and Canada taken as river mile 155.00. Table 5-1 lists the number of permitted users by trace data station reaches.

For Minnesota and North Dakota, permittees within each river reach were located via GIS mapping using township, range, and section data provided in the Minnesota and North Dakota permit databases. The locations for the permitted users in Manitoba were identified based on the river lot number and parish name obtained from the Winnipeg Land Titles Office. Manitoba permit locations were then plotted manually on the maps provided by the Winnipeg Land Titles Office. Having located all the listed permittees on regional maps, each permittee was identified according to the appropriate Red River of the North or Sheyenne River reach (see Appendix C).

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5.2.3 Interviews of Users

5.2.3.1 Selecting Interviewees

A primary goal of the investigation was to interview users of all types in each affected Red River of the North and Sheyenne River reach. In addition, the interview process focused on the highest volume users, under the assumption that they would be affected the most. Therefore, the database was sorted according to location (Minnesota, North Dakota, or Manitoba), type of use, and quantity of use, if reported. Interviewees were then selected according to the State/Province in which they are located and the type of use to obtain a diverse sample of uses along the entire reach of the study.

Based on the total of 201 permits, a representative sample of 39 permit holders (approximately 20 percent of the total) were to be interviewed. To determine how many of the users of each type would be interviewed, the number of interviewees within each user group was determined by multiplying the total number of interviews to be conducted (39 interviews) by the percentage of users that fall within each user type category. Table 5-2 shows the relative percentages of each user type and the number of permittees who were selected for interviews.

It should be noted that further examination of the list of 201 permits indicated that the number of permit holders would actually be less than 201. In many cases, a single person, facility, or municipality held more than one permit, but often the multiple permits were actually for the same use. Canadian officials provided no permit numbers with their list of permittees, so it is possible that duplicate entries for persons or corporate entities were erroneous, or actually represented only a single use. Furthermore, in Minnesota and North Dakota, a single permit can be subdivided (among, for instance, family members) resulting in multiple permit numbers and permit holders for what is essentially one permit. Taking these issues into account, the number of potential interviewees would be reduced to only 185.

Once the number of interviewees was determined for each user group, those who use the highest volume of water were selected first for interviews. However, because water usage information was not available for Manitoba users, interviewees who live in Manitoba could not be selected using this criterion.

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5.2.3.2 Interview Process

Phone numbers of the permittees selected to interview were obtained from public information sources, primarily the Internet. If the permittee was not contacted on the first call, a brief message was left explaining the purpose of the call, the information needed, and a toll-free number for the person to call back with the best time to contact them. If the individual failed to call back within 2 days, another call was placed. If the second call failed to contact the permittee, a second message was left. If the second message failed to produce results, the individual was removed from the interview pool and the next person was called. As stated, permitted users were contacted in descending order according to the user's volume of use.

When a permittee was contacted, the interview was conducted according to a predefined format. After an introduction, a brief description of the study intentions was presented to the interviewee. The interviewee was then asked if they were interested in providing their input by answering a few questions. The respondents were assured that the information gathered was for this study only and that it was not the intent of this study to locate permit violators. Those contacted who declined to be interviewed were encouraged to take the opportunity to voice their opinions. If offered, these concerns were recorded.

When respondents agreed to be interviewed, a first step was to confirm their use of the water from the Sheyenne/Red River of the North. If they were not in fact users (despite having been listed as a permittee), the respondents were allowed to voice any concerns about the proposed Devils Lake outlet. If water use was confirmed, the respondent was asked the following questions:

- 1. What do you currently use the water for, or what have you used the water for?
- 2. When do you use the water (which months or times of year)?
- 3. How much water would you say you withdraw (per day, per year, etc.)?
- 4. Are you currently satisfied with the quality of the water you withdraw from the river?
- 5. If not satisfied, why not?
- 6. How would you say a change in water quality would affect you? (For example, would you have damages to crops, livestock, or anything else?) Can you quantify what the dollar value of your loss would be?
- 7. What would be your solution/response to the above-mentioned concerns? Can you quantify what it would cost you?

Individual interview summaries are provided in Appendix E. The completed forms were used to develop an overall summary of the interviews.

During the interview process, it became apparent that few of the people interviewed were able to answer all of the questions listed above. Specifically, most interviewees were uncertain how a change in water quality would affect them and how they would respond to a change in water quality. Because such information was critical to this study, additional information related to these topics was collected through discussions with several State and Federal agencies and scientific experts. Further investigation was conducted (as described in Section 5.2.5) to attempt to determine whether or not the permitted users would actually be affected by water quality changes.

5.2.4 Type of Use

The permitted river water uses from North Dakota, Minnesota, and Manitoba were combined into the following use types for this study: irrigation, fish and wildlife, domestic, and other. Table 5-3 gives examples of each of these uses along with the number of permits for each use and timing of uses. Data for Table 5-3 were acquired both from permit listings and from permittee interviews.

5.2.5 Determination of Threshold Levels

5.2.5.1 Approach

The various types of permitted uses identified in Section 5.2.4 were analyzed to determine the potential effects of the Devils Lake outlet. Information on the potential effects on the uses was determined through available literature and contacts with agencies and/or specialists in each field. Research into the potential effects enabled computation of estimated "threshold" water quality levels for most uses, defined in this report as the level above which impacts may be detrimental and, if severe enough, might warrant correction or compensation for losses. It was assumed that minor water quality changes below these threshold levels are not likely to be detrimental for permitted users. Exceedance of the threshold was evaluated by use type. For each use, the trace data station reaches were evaluated as to its exceedance of the threshold by use type. In all cases, exceedance was computed based on Trace 6262. The reasons for using Trace 6262 are explained in Section 3.2.6.1.

5.2.5.2 Definitions

There is some variability in the nomenclature and units used when discussing the effects of "saline" water—water containing dissolved minerals or "solutes"—on plants and animals. Salinity is often thought of as "saltiness" which implies consideration of a particular salt, sodium chloride. However, many other salts may be dissolved in water. And although it is true that both chloride and sodium can have their own particular toxic effects on plants and animals, the effects of solute-laden water on living creatures go beyond the potential damage that may be caused by sodium chloride. For this reason, the sum of all dissolved matter in the water is of primary concern in discussions of salinity with respect to its effects on organisms.

The sum of all dissolved matter in water is generally expressed in milligrams per liter (mg/L) of TDS. TDS may in some cases refer to "total dissolved **solids**," and in some cases refer to "total dissolved **salts**." Whereas total dissolved **solids** includes all dissolved matter, including organic compounds, total dissolved **salts** actually includes only dissolved inorganic (mineral) compounds. For purposes of this study, the organic content of the water is considered to be insignificant compared to dissolved salts, so that the HEC-5/5Q-modeled TDS concentrations are used directly as an index of salinity (total dissolved salts are assumed to be equal to total dissolved solids).

Electrical conductivity (EC) of the water (also known as specific conductance) is a measure of TDS. Water with higher concentrations of dissolved salts are more conductive of electricity, and purer water is less conductive. EC is typically expressed in micromhos per centimeter (μmhos/cm)². The ratio, TDS/EC, typically ranges from 0.55 to 0.7 [in units of (mg/L)/(μmhos/cm)], depending on the ionic composition of the water. The TDS/EC ratio for Devils Lake water was evaluated by examination of USGS gage station water quality data and was found to be approximately 0.65. Therefore, the value of 0.65 was used in this study to convert EC (μmho/cm) to TDS (in mg/L).

5.2.5.3 Agricultural Crops and Cultivated Plants

Soil Salinity Relationship

The tolerance of crops, trees, shrubs, gardens, and grasses to TDS is directly related to the type of soil in which they are grown. Soil type affects the movement of water through the soil. Whether the water comes from rain or from irrigation sources, the pathways of the water are the same.

 $^{^2}Alternately,$ mhos are also called Siemens, and $\mu mho/cm$ is the same as $\mu S/cm$. The measurement of EC is usually standardized to 25°C, because conductivity changes with temperature.

Some of the water (the "leaching fraction") will percolate through the root zone and become part of the regional groundwater. Some of the water remains in the root zone as soil water. A portion of the water is taken up by the plant, where it either remains or is transferred back to the atmosphere via transpiration. Finally, a fraction of the water returns directly to the atmosphere via evaporation.

The leaching fraction for less-permeable (clayey) soils is lower than that for more-permeable (sandy) soils. Water passes slowly through clayey soils, so that it is exposed for longer periods of time to the warmest portion of the soil column. Evaporation effects are thus accentuated, and solutes tend to accumulate in the root zone as pure water is lost to evaporation. Another consequence of a lower leaching fraction is that the root zone is less easily "washed" by newly arriving water. The result is that the less-permeable soils are less likely to lose accumulated solutes.

Because of these considerations, less-permeable soils are considered to be less desirable when irrigation water is high in salinity. Other factors (irrigation amounts, timing of irrigation, climate, crop variety and growth stage, etc.) being equal, crops grown in such soils may be expected to be more susceptible to the potential adverse effects of saline water. In nature, some plant species have physiologically adapted to salinity in the root zone. Some of these species are grown in the horticulture industry and show higher-than-average tolerance for an accumulation of salts in the soil.

For this study, regional soil types were grouped according to the SCS hydrologic soil groups (A: high permeability soils, B: moderate permeability soils, C: low permeability soils, and D: very low permeability soils). Soil permeability data were required to estimate the leaching fraction of each soil type. The leaching fraction was assumed to be inversely related to permeability of the soil type—i.e., clayey soils would be expected to have a lower leaching fraction than sandy soils. Leaching fractions of SCS soil groups were assumed to range as follows:

! Soil Type A: 40 to 50%

! Soil Type B: 25 to 40%

! Soil Type C: 10 to 25%

! Soil Type D: 4 to 10%

Soils types along the rivers can be generally characterized as sandy loams with pockets of sand and clay along most of the Sheyenne River, and mainly clays with pockets of sandy loams through the

Red River Valley. Soils were characterized using information from the State Soil Geographic Database (STATSGO), and are based on Soil Conservation Service classifications.

Limitations of Salinity Tolerance Level Estimates

Much of the available data regarding salt tolerance levels of crops, trees, shrubs, gardens, and grasses are based on studies conducted in arid climates with sandy soils (California, Middle East, etc.). The carefully controlled nature of these studies makes it difficult to directly apply their results to irrigation along the Sheyenne River and Red River of the North. Many of these studies are based on experiments simulating arid climate conditions, so that evaporation rates are high. Furthermore, the studies typically supply irrigation water as the only water source for the crops being studied. In this way, a steady-state³ situation is eventually reached, wherein the salinity of the soil water in the root zone reaches a concentration plateau.

Clearly, this is not the situation for irrigated crops in Minnesota, North Dakota, and Manitoba, where irrigation is conducted only on an as-needed basis. During the (often long) periods when irrigation does not occur, salinity levels in the soils would be expected to decline because of the flushing effect of relatively ion-free rain and snowmelt water percolating through the root zone.

Unfortunately, crop salinity tolerance data derived for the conditions of midwestern irrigation are not available. Therefore, for this study, the threshold levels for salinity tolerance are based on data from the available studies—studies on plants subjected to high-evaporative environments with irrigation as the only water source. Similarly, the flushing effect of rain and snowmelt water was not taken into effect. As a result, the threshold levels presented below can be expected to be conservative—water of higher salinity could reasonably be expected to produce no ill effects on crops subjected to a typical irrigation regime in the study area.

The ionic composition of the TDS in the irrigation water used for the available studies is unknown. It is not known if the constituents of TDS would make a difference in the threshold level for the agricultural crops and cultivated plants. This information was not available.

Calculation of Threshold Levels Based on Study Data

³ According to the United States Salinity Laboratory (USSL) in Riverside, California, a non-steady state model is being developed which will better address the dynamics of different field conditions, including the impact of intermittent rainfall on soil leaching. However, the model will not be available for several more months and may in any case be difficult to apply to the particular conditions in the study area.

Agricultural Crops

The threshold levels of the various agricultural crops grown in the study area were computed based on the particular crop tolerance and the soil types. Table 5-4 lists the range of threshold levels by soil type for the agricultural crops. For purposes of this study, it was assumed that the average value would be used as the threshold level. The potential damages to agricultural crops would decrease the crop yield.

Dry edible beans appear to be the agricultural crop most sensitive to salinity; even in well-drained sandy soil (soil type A), these plants can tolerate only approximately 900 mg/L before a reduction in yield is experienced. Corn, flax, and potato yields would be affected in soils with moderate permeability; in clay and loamy soils (soil types C and D), these crops can tolerate approximately 700 mg/L before a reduction in yield is experienced. All other agricultural crops had threshold levels that were greater than 1,800 mg/L for all soil types.

Cultivated Plants

The permitted river water users involved in the production of cultivated plants include golf courses, ornamental plant nurseries, tree farms, fruit and vegetable truck gardens (sold at local roadside stands), and homeowners caring for private lawns. As with other plants, salinity in the root zone can reduce water uptake, restrict root growth, cause burning of the foliage, inhibit flowering, and limit fruit and vegetable yields. Sensitivity to soluble salts differs among plant species and their stage of growth. Seed germination and seedling growth are more sensitive to salt stress than the growth of mature plants. However, the tolerance level of non-agricultural plant species has not been studied by the scientific community to the extent that agricultural crops have been examined.

The threshold levels for selected garden crops and fruits that have been studied extensively were computed based on the plant's listed tolerance and the soil types in the study area. The range of threshold levels by soil type is listed in Table 5-5. The average value for the range was used as the threshold level for this study. The following garden crops and fruits are the most sensitive to salinity: beans, carrots, onions, lettuce, radishes, strawberries, and raspberries (threshold levels ranging from about 400 mg/L for soil type D to 1,100 mg/L for soil type A). Cabbage, peppers, spinach, sweet potatoes, apples, pears, grapes, plums, blackberries, and boysenberries are moderately sensitive to salinity (threshold levels ranging from about 700 mg/L for soil type D to 1,300 mg/L for soil type A). Beets, broccoli, cantaloupe, cucumber, and tomato are the least sensitive to salinity (threshold levels ranging from about 1,000 mg/L for soil type D to over 2,000 mg/L for soil type A).

For other non-agricultural plant species not studied in detail, Table 5-6 provides a partial listing of these plant species and their relative salt tolerance. According to this list, there are several trees and shrubs that are described as "non-tolerant" with plant damage expected at TDS concentrations of 0 to 1,400 mg/L. All other listed trees and shrubs are tolerant of salinity levels over 1,400 mg/L. The list also shows that all grasses are tolerant of salinity levels of over 1,400 mg/L.

5.2.5.4 Livestock

Agricultural statistics indicate that livestock raised in North Dakota and Minnesota includes cattle (both beef and dairy), sheep, hogs, and poultry. Of those counties along the Sheyenne River and Red River of the North, the percentage of cattle raised in 1997 ranged from 53 to 100 percent of total livestock⁴. Total head of sheep raised in 1997 ranged from 0 percent to 15 percent of total livestock. The total head of hogs raised in 1997 ranged from 0 percent to 47 percent of total livestock.

Livestock may be affected by elevated levels of dissolved solids in their drinking water. Available data indicates that threshold levels for water quality are most commonly discussed with respect to total dissolved solids (TDS) concentrations. Except for sulfate, TDS constituents (such as sodium, chloride, etc.) are not considered separately in discussing effects on livestock.

Adverse effects to all types of livestock and poultry are not expected to occur at concentrations below 1,000 mg/L TDS. Concentrations ranging from 1,000 mg/L to 3,000 mg/L generally cause no significant adverse effects with the exception of mild and temporary diarrhea in livestock or "water droppings" for poultry. According to the National Academy of Science and the North Dakota Agriculture Extension Service, water containing 3,000 mg/L of total dissolved solids (TDS) is generally satisfactory for most livestock. At concentrations ranging from 3,000 to 5,000 mg/L, young livestock may show poor feed conversion and impaired growth. Five thousand mg/L TDS is unacceptable for poultry.

Tolerance to sulfate is less than that for TDS. According to the University of Minnesota Extension Service, sulfate concentrations of 350 to 600 mg/L ingested by young animals may be associated with diarrhea, electrolyte imbalance, and sometimes death. Milk fat percentages may be lower in

⁴Agriculture statistics data do not provide information regarding poultry production as a fraction of total livestock production.

dairy cattle when consuming water above 600 mg/L sulfate. However, Canadian Water Quality Guidelines for livestock drinking water is 1,000 mg/L of sulfate.

Based on the available data as given above, the threshold level for TDS was assumed for this study to be 1,000 mg/L for poultry and 3,000 mg/L for all other livestock. The threshold level for sulfates was assumed to be 350 mg/L for all livestock assuming a zero tolerance for effects on very young animals.

5.2.5.5 Fish Hatcheries

Three water appropriation permits for fish and wildlife were identified (although it is likely that two of the permits are held by one facility). The U.S. Fish and Wildlife Service also holds five permits with use listed as "recreation." All facilities are in Barnes County, North Dakota, and appropriate water from the Sheyenne River. Annual water use information was obtained through telephone interviews with Cheryl Willis and Ginger Price of the U.S. Fish and Wildlife Service. Ms. Willis identified an average annual water appropriation of 170 acre-feet by the Bald Hill National Fish Hatchery and 1,000 acre-feet by the Valley City National Fish Hatchery. These appropriated volumes are well below the permitted water use appropriation for the six permits held by the facilities (total permitted appropriation of about 4,000 acre-feet). Ms. Price indicated that the river water is used throughout the year to raise sportfish (northern, walleye, perch, and bluegill) and some non-game species including catfish, sturgeon, and bony-tailed chub.

Relevant threshold values for fish hatcheries are the water quality standards developed by the U.S. EPA, as well as North Dakota's water quality standards for the protection of aquatic life. These standards are based on chronic toxicity of the most sensitive species and include a margin of safety. Therefore, they are very protective of fish. Unfortunately, for salt-related parameters, the only applicable U.S. EPA water quality standard is the criterion continuous concentration for chloride, which is 230 mg/L. North Dakota regulations for water quality standards (N.D. Chapter 33-16-02) classifies the Sheyenne River as a Class IA stream, which has a maximum limit for total chloride of 175 mg/L, a maximum limit for total sulfate of 450 mg/L, and a sodium limit defined as 60 percent of total cations as meq/L. Based on the HEC-5/5Q modeling results, the Sheyenne River will not exceed the chloride and sulfate limits with the additional flow from the Devils Lake emergency outlet. The sodium limit was not calculated, but sodium is not considered a toxic constituent to fish (see below).

Saline Sensitivities of Fishes

Salinity (i.e., total dissolved solids or soluble salts) affects the osmoregulatory ability of fishes (the process of maintaining fluid balance across membranes). In freshwater species, body fluids are maintained by active transport against external osmotic gradients. Fish gain water and lose ions through the gills, oral membranes, intestinal surface, and skin. Larval fish have less osmoregulatory ability and, therefore, are generally less tolerant than adult fish or eggs to salinity change.

A study, prompted by Peterka in 1971, examined the effects of various levels of saline water upon the fathead minnow (Pimephales promelas), northern pike (Esox lucius) and walleye (Stizostedion v. vitreum). These are considered to be important game species in rivers and lakes of North Dakota. More importantly, northern pike and walleye are raised in fish hatcheries that use the Sheyenne River water for raising fish. Results of laboratory experiments showed that eggs of all three species hatched well in water having a concentration of about 850 mg/L (specific conductance of 1,300 µmhos/cm), but there was no hatching of walleye and very poor hatching of northern pike eggs in water with a concentration of about 2,600 mg/L (4,000 μmhos/cm). Northern pike sac fry did not survive in water with a concentration of about 7,800 mg/L (12,000 µmhos/cm). An important limitation of this study was the selected salinity concentrations used in the study. Only the following four concentrations were tested: 325, 850, 2,600, and 3,900 mg/L (specific conductance of 500, 1,300, 4,000, 6,000 µmhos/cm). Thus, it is not known from this study how well the eggs would hatch in concentrations between 850 and 2,600 mg/L. This is a gap of critical information for the Devils Lake study because the concentrations could be as high as 1,100 mg/L, which is only 30 percent higher than the 850 mg/L concentration. Using the 850 mg/L as the threshold TDS value for the fish hatchery would be very conservative given the lack of information for egg hatching in water concentrations between 850 and 2,600 mg/L.

Peterka (1971) concluded that the ionic composition of the water is more important to fish survival than is the level of total dissolved solids (TDS). In Nebraska saline lakes, fathead minnows could not survive more than 2,000 mg/L TDS. Whereas in Saskatchewan and North Dakota saline lakes, fathead minnows were found in water of 15,000 mg/L TDS. The former were high in sodium bicarbonate and potassium carbonate, while the latter were higher in sodium and magnesium sulfate.

Hart et al. (1990) concluded that 1,000 mg/L salinity (i.e., TDS) was an appropriate threshold value for freshwater systems. This would protect the macroinvertebrates and plants, which were

considered more sensitive to salinity than the fish community. Therefore, based on this limited set of information, an appropriate threshold value is closer to 1,000 mg/L for TDS.

Two theses were also completed in 1990 and 1993 under John Peterka, at North Dakota State University, examining the salinity toxicity of fish in Devils Lake water. There are no changes from the work that Peterka reported on in the earlier studies reviewed above. There is information on the upper salinity limits for more fish species, but the theses do not include information on the species raised at fish hatcheries. There was some general information on the Devils Lake chain; such as, the salinity in Devils Lake is referred to as "sodium-sulfate type" waters.

Rieniets et al. (1987) discussed how exposing northern pike eggs to a NaCl solution (6.95 g/L) greatly improved the fertilization rate. This seems to counter the concerns about salinity toxicity, but it only calls for using the salt solution during fertilization, not raising the fish in it.

A recently completed AScI report on toxicity of Devils Lake water (August 1998) reported no significant toxicity to algae, Ceriodaphnia, or fathead minnows throughout most of Devils Lake. The one exception was in East Devils Lake, where the toxicity killed off the Ceriodaphnia.

Specific Ion Sensitivities

It is important to also look at the constituents of the TDS. The seven common ions that in sum constitute total dissolved salts are sodium (Na+), potassium (K+), calcium (Ca++), magnesium (Mg++), chloride (Cl-), sulfate (SO4--), and bicarbonate (HCO3-).

Aquatic test species have been shown to have different sensitivity to these ions (Tietge et al., 1994). The zooplankton species, Daphnia magna, and the fathead minnow (Pimephales promelas), in 48-hour observations, had the following comparative sensitivities (survival):

$$K+ > Mg++ > HCO3- > Cl- > SO4_$$

These test species did not show a significant response to changes in Na+ or Ca++. The relative sensitivity changes slightly in 96-hour observations, with HCO3- > Mg++. These test results indicate that sulfate is the least toxic constituent to the fish. In the Devils Lake with-outlet modeling results, sulfate appeared to be the primary contributor to the increase in instream-TDS with the additional flow from the emergency outlet. Because sulfate is the least toxic ion, it is possible that the increase in TDS may not impact the hatcheries at all.

Because fish tolerance data for sulfate was unavailable, threshold levels for sulfate (with respect to fish mortality) were not established for this report. For TDS, a conservative estimate of 1,000 mg/L was used in assessing potential impacts of the Devils Lake outlet.

5.2.6 Assessment of Potentially Affected Users

The assessment of affected users requires a breakdown of the permit data by reach and specific type of use (type of crop grown, type of livestock raised, type of grass grown, etc.). The threshold levels (as defined in previous sections) can then be used to identify which permitted users would be affected by the outlet operation. However, the permit information lists only the general type of use (irrigation, recreation, fish and wildlife, etc.). This general information identified the number of fish hatcheries. The remaining permitted users had to be more specifically identified to compute the number of potentially affected users.

The potential effects on permitted river water users are presented according to the stations referred to in Section 5.2.2. The river reaches are identified by their upstream and downstream boundaries. In each case, the upstream boundary is listed as the "Outlet," which for these purposes refers to point of discharge of the emergency outlet into the Sheyenne River. The downstream boundary is the trace data station downstream of which the threshold level is not exceeded. For example, "Outlet to Kindred" indicates that the threshold level is exceeded between the outlet's discharge point and some point upstream of Kindred (a point somewhere between Kindred and the next upstream station, Lisbon). "Outlet to Kindred" implies that nowhere downstream of Kindred would the threshold level be exceeded.

For purposes of this study, county-by-county agricultural use averages were used to estimate the number of users according to specific type of use. There are no data available from the counties that allowed differentiation of the amount of agricultural use from the amount of other uses (nurseries, golf courses, gardens, lawn, and domestic). Therefore, the information obtained from the user interviews was used to estimate the approximate percent of permittees that use the river water for agricultural use (50 percent) versus other uses (50 percent). The manner in which county data was used to further segregate use types is described below.

Agricultural Use

The agricultural use of river water was subdivided between crops and livestock using county data that provided the average per-county acreage of each. Since the county data were available by average acreage and the permittees use the river for multiple uses, the total potentially affected

acreage was estimated (rather than the total number of users). The potentially affected acreage per agricultural user was estimated based on conversations with the North Dakota Agricultural Extension Service. According to the Extension Service, the approximate maximum distance that irrigation equipment can draw from the river water is 1 mile. Therefore, irrigators were assumed to irrigate up to a maximum area encompassed by a 1-mile radius centered on the permit location.

The acreage that would be potentially affected was computed using the following data:

- ! Total acreage of crops and livestock (by county). The percentage of crops and livestock by county is listed in Table 5-7.
- Irrigated crops grown within each county (percent). The North Dakota and Minnesota Agricultural Statistics Service and Minnesota Department of Agriculture indicate that in counties within the Sheyenne and Red River of the North Basins, the following crops may be grown: barley, corn, dry edible beans, flax, hay, oat, potato, rye, soybean, sugar beets, sunflower, and wheat. The North Dakota statistics indicate that barley, corn, and wheat are the only irrigated crops in those counties. The percentage of irrigated crops was used for the determination of affected acreage in North Dakota. Minnesota statistics for irrigated crops are not available. For the analysis, it was assumed that the irrigated crops in Minnesota would be the same as in North Dakota (barley, corn, and wheat). The percentages of each crop were based on the total agricultural crops grown. The maximum and minimum acreages of crops (in percent of total agricultural acreage) in these counties is listed in Table 5-8.
- ! Livestock types raised within each county (percent). Livestock types by percentage raised in this region is listed in Table 5-9.
- ! Soil types (based on the SCS hydrologic soil group) were estimated using the STATSGO soils database. Soil types were identified within the 1-mile radius of the location of each irrigative permit holder. The resulting acreage by soil type for irrigative users is listed in Table 5-10.

Cultivated Plants

No county data were available to allow quantification of non-crop (trees, shrubs, lawns, garden vegetables, etc.) plant production. Furthermore, from the interviews, it appears likely that each permittee uses the river water to grow more than one non-crop species. The only way to actually obtain the type of specific use or the affected area would be to contact each permittee. Rather than trying to determine numbers of users producing specific types of non-agricultural plants, these users were considered in aggregate for purposes of this report.

5.2.7 Water Supply Alternatives and Costs

For permitted users affected by outlet operations, several potential water supply alternatives were considered. These options included well installation, connection to rural water supply, installation of a well and supply system for multiple permitted users, withdrawal from local tributary streams, or reimbursement for crop damage. An analysis of these alternatives with approximate costs (where applicable) for each is discussed below. A comparison between the alternatives is located in Section 5.3.5.

! Well Installation

As discussed in Section 3.2.7, the two deep aquifers in this region are the Dakota (part of the Dakota Group) and the Pierre (part of the Montana Group). In most locations, these deep aquifers have typical water yields of less than 10 gpm, as listed in Table 5-11. In addition, the high salinity of these deep aquifers makes them unsuitable for many of the permitted uses. Therefore, the only usable groundwater source is the surficial (glacial drift) formations shown on Figure 3.

The water quality and yield data for the glacial drift aquifers are listed in Table 5-12. To provide an alternate water source for irrigators, an aquifer would have to be located in the immediate vicinity of the water users. However, glacial drift aquifers are not abundant throughout the study area (see Figure 3) and are not available for many locations. The surficial aquifers that are located along the river basins are heavily appropriated and additional permits are not easily obtained. There are no glacial drift aquifers along the entire study reach of the Red River of the North. In most cases, therefore, well installation would not be an option because of the relatively few locations where glacial drift aquifers are located. Permit holders would have to be considered on a case-by-case basis to locate the few users for which installation is actually an option.

Costs for well installation in the glacial drift aquifers would range from approximately \$20,000 to \$30,000, depending on the depth and capacity of the well. O&M costs for well operation would be similar to those currently experienced by irrigators using river water.

! Rural Water Supply

To evaluate the feasibility of providing irrigation water via rural water suppliers, rural water suppliers were contacted in both the Sheyenne River Basin and the Red River of the North Basin. Without exception, the rural water suppliers indicated that they provide water to

farmers for domestic use, but do not have the capacity to provide farmers with water for irrigation purposes. They also indicated that it would be prohibitively expensive to irrigate with water supplied from the rural water suppliers. As a result, rural water supply was ruled out as an alternative water source for permitted river water users for irrigation of crops. However, in some cases, rural water supply may provide an alternative water source for permitted river water users that water only gardens and lawns. The additional costs would be the per gallon charge for the additional water used (estimated to be \$3.70/1,000 gallons).

! Well Installation and Supply System for Multiple Users

The installation of a well for multiple water users would require locating an available aquifer that could provide the required flow capacity for several permitted water users. This would require a high-capacity well; however, high-yield aquifers are scarce within the study area. Even if aquifers having adequate capacity could be located, capital costs and operational considerations make it unlikely this potential water supply option would be implemented.

! Withdrawal from Tributary Stream

It is possible that some of the permitted river water users could switch from using the Sheyenne River or Red River of the North to using river water from a tributary stream. This would be dependent on the location of the permitted user, the distance to a tributary stream, the water quality of the tributary stream, and the flow capacity in the tributary stream. Only a very few irrigators could potentially use local streams, and each permitted user would require a separate analysis to determine if this would be a feasible alternative.

! Reimbursement for Damages

It may not be economically feasible to provide an alternate water supply for irrigators that experience detrimental impacts warranting correction or compensation. An alternative compensation could be to reimburse irrigators experiencing reduced yields due to outlet operations. This could potentially be more cost-effective since damages would occur only during years that the outlet operation produced high concentrations.

The implementation of a reimbursement system for damages would be very complicated and difficult to administer. For example, it would be difficult to determine which percent of any crop damages were the result of weather, flooding, heat stress, and/or agricultural management, and which were the result of the Devils Lake outlet. Such a compensation system would also

require an analysis of each user's actual irrigation amount to determine the acreage of crops grown, the number of livestock raised, the acreage of cultivated plants or lawns, etc.

5.3 Results

5.3.1 Permit Listing

A complete listing (sorted by river reach) of the other permitted (untreated) river water users identified for this study is provided in Appendix C. The Sheyenne River and Red River of the North permittees by reach are identified on Figure 1.

During the interview process, it was discovered that some of the information provided from the permitting agencies was not current and/or accurate. In particular, some of the permittees listed on the Manitoba Water Resources database were no longer using the permit, were no longer living at the address provided, or were deceased. To maintain consistency, and because not every listed Manitoba permittee could be contacted, inactive permittees were nevertheless allowed to remain on the list. Therefore, the total number of active permitted users in Manitoba is actually less than the number (74) identified in the database. Conversations with interviewees indicated that the North Dakota and Minnesota database records were generally accurate and current.

5.3.2 Location of Permittees

Red River of the North river miles increase from zero at Lake Winnipeg to 427.5 at the confluence with the Sheyenne. Sheyenne River miles increase from zero at its mouth to 463.2 at the outfall of the proposed Devils Lake outlet. Six reaches between trace data stations were identified along the Red River of the North, and five reaches were identified along the Sheyenne River (Figure 1). The number of permitted users by reach is given in Table 5-1.

Examination of Figure 1 and Appendix C indicates a varying distribution of permits along the Sheyenne River and the Red River of the North. Several reaches along the Red River of the North show somewhat higher concentrations of permits: Reach 11 (in Manitoba) has 74 permits, and Reaches 9, 7, and 6 all have between 15 and 35 permits. Reaches 1 and 5 (along the Sheyenne River) show a smaller concentration of permits than the other Sheyenne reaches. Because of incomplete data regarding actual water withdrawal associated with each permit, it is difficult to assess the relation between the number of permits and water withdrawal within a given river reach.

5.3.3 Concerns of Water Users

Interview summaries for each permitted user interview are provided in Appendix E. Holders of 39 distinct permits were interviewed for this report. However, two of those interviewed actually held two permits. As a result, the total number of interview summaries given in Appendix E is 37, which is taken as the number of interviewees in the following discussion.

Table 5-13 summarizes the data gathered through interviews with permit holders. The table summarizes the concerns of the respondents with respect to potential impacts of the proposed Devils Lake outlet. Also given are the interviewees' responses with respect to possible water supply options and estimates of water supply costs. The summary of water supply options and costs presented in Table 5-13 is based only on interview responses.

About half of the interviewees (18 out of 37) along the Sheyenne River and Red River of the North were concerned with potential water quality impacts. Several of the interviewees also expressed concern over the increased water quantity, which they felt may result in increased flooding and river bank erosion. Another interviewee had no concerns over water quality but was concerned about the increase in water quantity. Ten of those interviewed had no concerns whatsoever with respect to the proposed outlet from Devils Lake. One expected that the pumping would in fact be beneficial for his purposes. Some of those who were unconcerned believed that the Devils Lake water would be sufficiently diluted and the change unnoticeable by the time it reached them. Still others already had an alternative water source readily accessible to them. Seven had no opinion or were unsure of how to assess the likely impacts.

5.3.4 Potentially Affected Users

The number of potentially affected users was calculated based on the HEC-5/5Q modeling results for Trace 6262 (with-outlet) and the threshold levels calculated as described in Section 5.2.5.

5.3.4.1 Agricultural Crops and Cultivated Plants

Agricultural Crops

In nearly all counties within the study area, wheat and corn are the most widely planted irrigated crops. The percentages of wheat acres planted range from 4 to 87 percent; the percentage of corn acres planted range from 0 to 96 percent. Barley is the only other irrigated crop planted in these counties (0 to 50 percent). All other crops grown in the region are not listed as being irrigated.

According to the North Dakota Agricultural Extension Service, the irrigation of agricultural crops typically occurs between May and September. Therefore, the maximum monthly averages of water quality constituents for each HEC-5/5Q trace data station were obtained using these 5 months for determination of threshold level exceedances. Study results presented in Table 5-4 show that corn is the only crop irrigated in this region that may be affected by the water quality data indicated in Trace 6262 during the growing season. Table 5-14 lists the reaches in which the threshold levels are exceeded for both with- and without-outlet conditions. Dry edible beans, flax, and potatoes are also listed as being potentially affected by salinity concentrations under both without- and withoutlet conditions. These crops were not listed as being irrigated crops in this region.

Comparison of without-outlet trace data to threshold levels indicates that corn yields could be affected from the outlet to Valley City for type B soils. For clayey soils, threshold tolerance is less, so that areas from the outlet to Grand Forks may be affected under existing conditions. According to the Trace 6262 levels, corn yields under with-outlet conditions could be affected from the outlet to Kindred for well-drained sandy soils and as far as Lake Winnipeg for clayey soils. The total acreage of corn that are listed as being potentially affected without the outlet is approximately 13,900 acres. The potentially affected acreage of corn increases to approximately 24,700 acres under with-outlet conditions.

Cultivated Plants

Based on Trace 6262 with-outlet data, the salinity levels during the irrigation months (May through September) are less than 1,400 mg/L TDS along the entire Sheyenne River and Red River of the North. Therefore, it can be assumed that no effects would be reported for grasses used at golf courses or for watering lawns. (Threshold TDS levels for these uses have been estimated to be 1,400 mg/L, as presented in Section 5.2.5.)

The most sensitive cultivated plants (beans, carrots, onions, radishes, strawberries, and raspberries) would potentially be affected by without-outlet irrigation for the reach from the Devils Lake outlet to Valley City for soil type B and from the Devils Lake outlet to Grand Forks for soil type D. These sensitive plants would be affected by with-outlet TDS concentrations from the Devils Lake outlet to Kindred for soil type A or Lake Winnipeg for soil type D. Cabbage, lettuce, peppers, spinach, sweet potatoes, tomatoes, apples, pears, grapes, plums, blackberries, and boysenberries will potentially be affected by with-outlet irrigation from the Devils Lake outlet and Valley City for soil type B and Grand Forks for soil type D. Some of these plants would also be affected by the without-outlet TDS concentrations. Table 5-15 lists the trace data station reaches where potential effects may be seen

(based on Trace 6262 concentrations for both with- and without-outlet). Table 5-6 provides relative salt tolerances for other cultivated plants.

5.3.4.2 Livestock

The assumed TDS threshold level of 1,000 mg/L for poultry is exceeded for the with-outlet Trace 6262 from the outlet to the confluence of the Sheyenne River and the Red River of the North. This threshold level is not exceeded by the without-outlet Trace 6262. The effects of exceeding the threshold level would be mild and temporary diarrhea or water droppings, which would likely have a greater effect on the young. The quantity of poultry raised by permittees that use river water is unknown. Because the county data does not include poultry, it may be assumed that there are relatively few permittees that use river water to raise poultry. However, the exact number cannot be obtained without contacting each permittee.

The assumed TDS threshold level of 3,000 mg/L for all other livestock is not exceeded for the withoutlet Trace 6262. Therefore, it can be concluded that there would not be adverse effects from TDS on other livestock.

The assumed sulfate threshold level of 350 mg/L for livestock is exceeded for the with-outlet Trace 6262 from the outlet to the confluence of the Sheyenne River and the Red River of the North. The potential for effects is limited to young animals at sulfate levels between 350 mg/L and 450 mg/L. The effects of exceeding the threshold level would be diarrhea or electrolyte imbalance, which may even cause death in rare cases. As with poultry, the exact number of livestock producers cannot be obtained without contacting each permittee.

5.3.4.3 Fish Hatcheries

The U.S. Fish and Wildlife Service is listed as having ten permits, although this study identified only two fish hatcheries (Bald Hill and Valley City hatcheries, both located in Barnes County, North Dakota). The Trace 6262 with-outlet data indicates a maximum monthly average TDS concentration of about 1,050 mg/L in this reach. This TDS concentration is approximately at the threshold level, which indicates that there would be a potential for effects. The effects would likely be more prevalent in larval fish, affecting the fishes osmoregulation (the fluid balance across membranes). The extent of potential damages would be dependent on the type of fish raised, the age of the fish, any treatment of the water, and the timing of river water use.

5.3.5 Water Supply Alternatives and Costs

As identified in Section 5.2.7, the water supply alternatives for the non-municipal non-industrial permitted users consist of the following:

- ! Well installation
- ! Rural water supply connection
- ! Well installation and supply for multiple users
- ! Withdrawal from tributary stream
- ! Reimbursement for damages

Based on analysis of groundwater supplies, on interviews with state and local officials, and on interviews with rural water suppliers, it is unlikely that any alternate supply relying on groundwater will be feasible for affected irrigators. If groundwater supplies are available, well costs are estimated at \$20,000 to \$30,000 per user. If rural water supplies were adequate for smaller irrigative uses, costs for purchasing water will be approximately \$3.70 per 1,000 gallons. The costs for establishing a small local supply system are likely to be prohibitive and were not evaluated for this report.

In the few cases where it may be feasible, switching to a small local stream is unlikely to generate significant additional costs for irrigative users.

Cost estimates were not made for providing compensation for reduced yields. Such costs would be difficult to assess and would have to be developed on a case-by-case basis.

5.4 Discussion

5.4.1 Water Quality Concerns Expressed by Users

5.4.1.1 Irrigation

As can be seen in Table 5-3, the majority of the permitted users along the Red River of the North and Sheyenne rivers withdraw water for irrigation purposes. The main concern of most of those involved in agricultural production was with the expected increase in salinity and/or hardness. Many of the farmers interviewed could not quantify the loss they would experience except for that the loss would be "astronomical" or "unimaginable." Loss estimates that were provided by the farmers ranged from \$200 per acre per year to \$5,000 per acre per year. Some indicated that a large change in water quality would make continuation of farming impossible. Relocation costs

might have to be taken into account if alternative water supply expenses proved to be too great to allow farming to continue profitably.

A representative of the Glenlea Research Station, part of the University of Manitoba, felt that the station uses 5 percent of the water it takes from the Red River of the North for irrigation of crops, flowers, and lawns. The remaining 95 percent of the water used by the station is for livestock watering. According to the interviewee, water is pumped from the Red River of the North once during the summer and once in February and is stored in a 1- to 1.5-million-gallon reservoir. The water is pumped from the reservoir to an onsite treatment system. The interviewee indicated that an increase in salinity would cause problems for the animals and that the salt may cause equipment problems. Because an alternative water source is not available, the interviewee speculated that the station might be forced to move to another location. He was not able to provide damage or relocation cost estimates.

Golf course irrigators were also very concerned about a potential increase in salinity. Greenskeepers predicted the change in water quality could cause damage to their fairways and greens causing them to "burn up." One Manitoba interviewee estimated that the loss in revenue (a reduction in the number of golfers) due to turf damage would be about \$400,000 per year for an 18-hole course and \$200,000 per year for a 9-hole course, and it would cost \$15,000 to \$20,000 to replace one damaged green. A possible water supply option for the golf course would be to connect to city water. The interviewee estimated that purchasing this water would cost about \$20,000 per year for an 18-hole course and \$8,000 per year for a 9-hole course. In addition, the interviewee expressed concern that if city water was in high demand, the recreational users (i.e., golf courses, parks, etc.) would be the first to lose their water rights. He also indicated (as many interviewees did) that installing a groundwater well was not an option because the regional groundwater is too saline. Irrigation of city parks and lawns could also be adversely affected by a change in water quality. However, the parks district manager for the City of Grand Forks indicated that it would probably be possible to simply tap into the city water supply, which would result in very little additional cost.

5.4.1.2 Recreational and Fish and Wildlife

The U.S. Fish and Wildlife Service (FWS) indicated that there are no specific water quality requirements for their fish hatcheries but that there are several water quality parameters that could adversely affect stream fish. The FWS also indicated that there are no other water sources

that they could feasibly use. Those interviewed were concerned that a decline in fisheries productivity would result in lost recreational opportunities that could cost several million dollars.

5.4.2 Water Quantity Concerns of Users

Several of the interviewees were not concerned about the water quality issues but mentioned water quantity issues as being of prime concern. They indicated that the water levels along the river have been increasing significantly over the past few years, and any additional water pumped to the river could exacerbate severe erosion problems along the river banks and would compound the flooding problems that are already occurring. One North Dakota farmer mentioned that when his fields are flooded it costs him approximately \$100 per acre to reseed his alfalfa crops. Another problem, that was presented by some interviewees, is that large fluctuations in water level causes problems for their irrigation intake pumps. To redesign and install a pumping station capable of operating over a greater range in water levels is very expensive. Such reinstallation costs about \$50,000, according to one North Dakota farmer who recently installed such a system.

5.4.3 Potential Effects on Other Permitted Users

The potential effects to other permitted (untreated) river water users was difficult to quantify with the available data. The results listed in this section are only preliminary approximations of the potential effects. The effects based on Trace 6262 concentrations can be grouped by the various uses. It should be emphasized that these effects are highly dependent on the trace data, which reflect only one possible "future" and outlet operation scenario.

- ! The only irrigated agricultural crop potentially affected by the increased TDS concentrations is corn that is grown in low-permeability soil types. The potentially affected agricultural crop acreage is listed in Table 5-16. A total of about 24,700 acres of corn was estimated to be potentially affected with the outlet. However, even without the outlet, approximately 13,900 acres of corn were estimated to be affected by high salinity levels. This may indicate that other crops may currently be planted in these areas and that the assumptions for the analysis do not represent the actual crops grown in this area.
- ! Cultivated plants can be highly sensitive to salinity, and many are affected to both with- and without-outlet conditions. There are very few data available on the amount of cultivated plants grown and, therefore, no estimates of potentially affected acres can be computed. Grasses are more tolerant of salinity, and, based on the available data, would not be affected by the outlet.

- ! Livestock effects would be limited to young animals and poultry from the outlet to the confluence of the Sheyenne and Red River of the North. The lack of data on livestock raised along these reaches prohibits an estimate of the number of livestock potentially affected by the outlet. The effects would likely be diarrhea, electrolyte imbalance, and sometimes death in young animals.
- ! Fish hatcheries in Barnes County would experience TDS concentrations at the threshold level. The extent of potential damages would be dependent on the type of fish raised, the age of the fish, the treatment of water, and the timing of river water use.

5.4.4 Water Supply Alternatives and Potential Costs

5.4.4.1 Perceptions of Interviewees

Reliable estimates of potential crop damages were difficult to obtain. One Manitoba farmer suggested that a water supply option would be to change the types of crops that he irrigates from raspberries to wheat and that such a change would result in a revenue loss of \$4,320 per acre per year. A North Dakota farmer suggested that if he were to stop irrigating his 100 acres of corn and beans altogether, he would experience a loss of \$190 per acre per year.

An obvious water supply option to permitted users who become unable to make use of river water is to install a groundwater well and pumping system. However, many of the people who were interviewed indicated that installing a well is not feasible. Interviewees anticipated several problems with well installations, including prohibitive depth to groundwater, poor groundwater quality (unacceptable salinity levels), cold groundwater temperatures making the water difficult to use for some purposes, and low-yield regional aquifers. Such problems may make well installation unacceptable or too expensive.

For some users, connecting to city water appears to be the least expensive water supply alternative. For irrigators, however, the large quantity of water needed may make purchase of water quite expensive. Costs for purchasing water were difficult to estimate because they may vary greatly, depending on seasonal rainfall amounts, type of crop, and soil type. Furthermore, for many river water users, the great distance to the nearest municipality makes connection to a city water supply infeasible.

A mitigation option mentioned by several of the interviewees was complete relocation of their operation. Interviewees found the costs of such relocation difficult to estimate.

5.4.4.2 Assessments Based on Study Analysis

In contrast to the perceptions of interviewees, available data and computed threshold levels for salinity tolerance indicate that few, if any, users are likely to be affected by changes in water quality resulting from outlet operation. These threshold levels are likely to be extremely low for crops grown in this region, so that the exceedances could actually be much less frequent than expressed in this study. Salinity tolerance listings are based on the assumption that irrigation water is the sole water source for the crop in question. Such is clearly not the case in the study area, where irrigation is only necessary when rainfall is deficient and affects from the outlet only occur infrequently (during years when the outlet is operating). Any long-term effects on soils would be reduced or eliminated by subsequent rainfall events that would leach the high concentrations from the irrigation water out of the soil.

In addition, the trace data used (Trace 6262) for determining the existence of threshold value exceedance is not likely to represent future water quality under with-outlet conditions. Water quality is likely to be significantly better than that presented by Trace 6262.

If mitigation should be required to compensate growers for damages, it is unlikely that provision for an alternate water source will be a feasible option for most users. However, it will be complicated to develop a means of directly compensating users for losses incurred as a result of outlet operations. The costs of such a compensation scheme are not evaluated for this report.

5.5 Summary

Most of the permitted water users along the Sheyenne River and the Red River of the North use the river water for irrigation purposes. Irrigation includes agricultural crops and cultivated plants (park, cemetery, nursery, gardens, etc.). Because this is the most common use, most of the users withdraw water from the river during the growing season and drier months. The quantity of water withdrawn from the rivers varies from year to year for each of the irrigators, because the quantity is largely dependent on what they are irrigating and the seasonal rainfall amount.

It is difficult to quantify the number of permitted users that will be adversely affected by outlet operations. However, based on research and calculations completed for this study, it appears that the extent of such effects on these users will not be great. The only irrigated agricultural crop potentially affected by the increased TDS concentrations is corn grown in low-permeability soils (estimated at approximately 17 square miles).

Mitigation for any damages to crops, lawns, livestock, etc. would likely take the form of compensation for lost yields.

Section 5 Tables

Permitted Users between Trace Data Stations
Permitted Users by Permit Type and Location
Permitted Water Use Types and Timing of Use
TDS Threshold Levels for Agricultural Crops
TDS Threshold Levels for Cultivated Plants
Relative Salt Tolerance of Various Cultivated Plants
Percent of Crops Grown and Livestock/Other Farmland Uses
Agricultural Crops Acreage Planted in 1997
Percent of Livestock Raised
Soil Types within 1 Mile of Permitted Users
Deep Aquifers
Glacial Aquifers
Perceived Devils Lake Outlet Operation Effects on Permitted Users
Reaches that Exceed the TDS Threshold Levels for Agricultural Crops
Reaches that Exceed the TDS Threshold Levels for Cultivated Plants
Potentially Affected Agricultural Crop Acreage

Table 5-1

Permitted Uses

Listed Between Trace Data Stations

		Number of	
Use	State/Province	Permitted Users	% of Grand Total
Red River of the No			
ited itiver of the ite	Between Lake Winnig	neg and Emerson	
Irrigation	Manitoba	73	
Domestic	Manitoba	1	
Waterfowl Conservation	Manitoba	1	
Other	Manitoba	1	
Other	Subtotal:	76	38%
	Between Emersor		3070
Irrigation	North Dakota	15	
Irrigation	Subtotal:	15	7%
			1 /0
Irrigation	Between Drayto		
Irrigation	North Dakota Subtotal:	5 5	2%
			2/0
luui natian	Between Oslo and		
Irrigation	North Dakota	9	
Major Crop Irrigation	Minnesota	7	
Golf Course	Minnesota	1	00/
	Subtotal:	17	8%
1	Between Grand For		
Irrigation	North Dakota	20	
Major Crop Irrigation	Minnesota	15	470/
	Subtotal:	35	17%
There were no nermitted	Between Halstad a users identified between Halsta	and "Junction"	
	dsers identified between Haiste	ad and Sunction	
Sheyenne River	Detuges II I westing	all and Kindrad	
Irrigation	Between "Junction North Dakota	n" and Kindred 7	
Irrigation	Subtotal:	7	3%
	Between Kindred	-	370
Irrigation	North Dakota	15	
migation	Subtotal:	15	7%
	Between Lisbon a		1 70
Irrigation	North Dakota	15	
Fish & Wildlife	North Dakota	1	
1 Ion a vilalio	Subtotal:	16	8%
	Between Valley City a		<u> </u>
Irrigation	North Dakota	5	
Recreation	North Dakota	3	
Fish & Wildlife	North Dakota	2	
I IOI A TYNAMO	Subtotal:	10	5%
	Between Cooperstown an		070
Irrigation	North Dakota	5	
migation	Subtotal:	5	2%
		201	
	Grand Total:	201	100%

Table 5-2

Permitted Users by Permit Type and Location

Permit Location and Type	Percent of Permits	Number of Permittees Interviewed
Manitoba		
Irrigation	31%	12
Waterfowl Conservation	<1%	0
Domestic	<1%	0
Other	<1%	0
North Dakota		
Irrigation	54%	21
Fish & Wildlife	1%	1
Recreation	1%	1
Minnesota		
Irrigation	10%	4

(Note that while the total number of Permittees interviewed was 39, the number of interviews actually conducted was 37. Two of those interviewed were holders of two separate permits.)

Table 5-3

Permitted Water Use Types and Timing of Use

Type of Use & Number of Permits in Each State/Province	Description/Examples	Timing of Use
Irrigation ! 73 in Manitoba ! 96 in North Dakota	Crop Irrigation (corn, alfalfa, potatoes, strawberries, etc.)	Crops are irrigated during the growing season (mostly between May and August)
! 23 in Minnesota	Non-Crop Irrigation (cemeteries, golf courses, tree nurseries, etc.)	Golf courses irrigate May to September; lawns and cemeteries are irrigated throughout non-frozen periods
	Livestock watering (see note below)	Throughout the year
Fish & Wildlife ! 1 in Manitoba ! 6 in North Dakota	Fish hatcheries	Throughout the year
Domestic ! 1 in Manitoba	Domestic use (drinking, washing, etc)	Throughout the year
Other ! 1 in Manitoba	The permitted use was listed as "other"	Unknown

Notes: Permitted use types listed in this table are groupings that combine the permit information from the two States and Province. Permitted use types include livestock watering under the general heading "Irrigation."

Table 5-4 TDS Threshold Levels for Agricultural Crops

	TDS Threshold Level (mg/L)					
CROPS	Soil Type A	Soil Type B	Soil Type C	Soil Type D		
Barley	67 53 - 7429	4906 - 6753	3852 - 4906	2889 - 3852		
Corn	1435 - 1579	1042 - 1435	818 - 1042	614 - 818		
Dry Edible Beans	844 - 929	613 - 844	481 - 613	360 - 481		
Flax	1435 - 1579	1042 - 1435	818 - 1042	614 - 818		
Hay*	4474 - 4921	3250 - 4474	2552 - 3250	1914 - 2552		
Oats	N/A	N/A	N/A	N/A		
Potato	1435 - 1579	1042 - 1435	818 - 1042	614 - 818		
Rye	4726 - 5200	3434 - 4726	2696 - 3434	2022 - 2696		
Soybean	4220 - 4643	3065 - 4220	2407 - 3065	1805 - 2407		
Sugarbeet	5909 - 6500	4292 - 5909	3370 - 4292	2528 - 3370		
Sunflower	N/A	N/A	N/A	N/A		
Wheat	5064 - 5571	3679 - 5064	2889 - 3679	2166 - 2889		

^{*} Barley Hay

Notes: N/A denotes information not available for that crop.

Soil types are based on SCS hydrologic soil types as follows:

Type A Low runoff potential: high infiltration rates.

Type B Moderate infiltration rates.

Type C Slow infiltration rates.

Type D High runoff potential: slow infiltration rates.

Table 5-5
TDS Threshold Levels for Cultivated Plants

	TDS Threshold Level (mg/L)				
PLANTS	Soil Type A	Soil Type B	Soil Type C	Soil Type D	
Beans	844 - 929	613 - 844	482 - 613	361 - 482	
Beets	3376 - 3714	2452 - 3376	1926 - 2452	1445 - 1926	
Broccoli	2363 - 2600	1717 - 2363	1348 - 1717	1011 - 1348	
Cabbage	1519 - 1671	1104 - 1519	866 - 1104	650 - 866	
Cantaloupe	1857 - 2043	1349 - 1857	1060 - 1349	795 - 1060	
Carrot	844 - 929	613 - 844	482 - 613	361 - 482	
Cucumber	2111 - 2321	1533 - 2111	1203 - 1533	903 - 1203	
Lettuce	1098 - 1207	797 1098	626 - 797	470 - 626	
Onion	1013 - 1114	735 - 1013	578 - 735	434 - 578	
Pepper	1266 - 1393	920 - 1266	722 - 920	541 - 722	
Radish	1013 - 1114	735 - 1013	578 - 735	434 - 578	
Spinach	1688 - 1857	1227 - 1688	963 - 1227	722 - 963	
Sweet Corn	1435 - 1579	1043 - 1435	818 - 1043	614 - 818	
Sweet Potato	1266 - 1393	920 - 1266	722 - 920	541 - 722	
Tomato	2111 - 2321	1533 - 2111	1203 - 1533	903 - 1203	
Apple, pear	1435 - 1579	1043 - 1435	818 - 1043	614 - 818	
Grape	1519 - 1671	1104 - 1519	866 - 1104	650 - 866	
Strawberry	844 - 929	613 - 844	482 - 613	361 - 482	
Plum	1266 - 1393	920 - 1266	722 - 920	541 - 722	
Blackberry	1266 - 1393	920 - 1266	722 - 920	541 - 722	
Boysenberry	1266 - 1393	920 - 1266	722 - 920	541 - 722	
Raspberry	844 - 929	613 - 844	482 - 613	361 - 482	

Soil types are based on SCS hydrologic soil types as follows:

Type A Low runoff potential: high infiltration rates.

Type B Moderate infiltration rates.

Type C Slow infiltration rates.

Type D High runoff potential: slow infiltration rates.

Table 5-6

Relative Salt Tolerance of Various Cultivated Plants

Non Tolerant (0–1,400 mg/L)	Slightly Tolerant (1,400–2,800 mg/L)	Moderately Tolerant (2,800-5,600 mg/L)	Tolerant (5,600-11,200 mg/L)
Nurseries			
azalea cottoneaster red pine rose sugar maple viburnum white pine	apple forsythia linden Norway maple red maple	black locust boxwood beet red oak white ash white oak	arborvitae juniper Russian olive
Truck Gardening			
begonia blueberry carrot green bean onion pea radish raspberry strawberry	cabbage celery cucumber grape lettuce pepper potato snapdragon sweet corn	broccoli chrysanthemum geranium marigold muskmelon spinach squash tomato zinnia	asparagus Swiss chard
Golf Courses	creeping bentgrass Kentucky bluegrass perennial ryegrass red fescue	nugget Kentucky bluegrass seaside creeping bentgrass	alkaline grass

Source: Soil Test Interpretations and Fertilizer Management for Lawns, Turf Gardens, and Landscape Plants

Table 5-7

Percent of Crops Grown and Livestock/Other Farmland Uses

	Total Acres	Agricu	Itural Crops	Lives	stock/Other	
County	Farmed	%			Acres	
Red River of the North						
Minnesota						
Kittson	483,000	62.0%	299,400	38.0%	183,600	
Marshall	744,700	64.3%	479,200	35.7%	265,500	
Norman	457,700	71.5%	327,100	28.5%	130,600	
Polk	1,042,900	61.6%	642,100	38.4%	400,800	
North Dakota						
Grand Forks	769,200	86.9%	668,400	13.1%	100,800	
Pembina	600,800	88.1%	529,300	11.9%	71,500	
Traill	501,100	99.8%	500,100	0.2%	1,000	
Walsh	737,300	76.4%	563,100	23.6%	174,200	
Wells	750,900	71.3%	53 5 ,1 00	28.7%	215,800	
Red River Subtotal	3,359,300	83.2%	2,796,000	16.8%	563,300	
		Sheyen	ne River			
Barnes	858,300	78.5%	673,900	21.5%	184,400	
Benson	777,700	55.4%	430,800	38.2%	296,900	
Cass	1,070,500	90.9%	973,200	9.1%	97,300	
Eddy	369,100	57.3%	211,500	42.7%	157,600	
Griggs	396,200	70.3%	278,600	29.7%	117,600	
Nelson	552,700	68.1%	376,600	31.9%	176,100	
Ransom	485,000	66.8%	323,800	33.2%	161,200	
Richland	799,600	96.3%	770,000	3.7%	29,600	
Steele	439,80 0	83.8%	368,400	16.2%	71,400	
Sheyenne R. Subtotal	5,748,90 0	76.7%	4,406,800	22.5%	1,292,100	
Total	9,108,200	79.1%	7,202,800	20.4%	1,855,400	

Based on 1992 Agriculture Census

Table 5-8

Irrigated Agricultural Crops Acreage Planted in 1997

Minnesota						
Ag. Crop Min (%) Max (%)						
Barley	11.4%	17.6%				
Com	1.8%	2.4%				
Beans	0.0%	0.0%				
Flax	0.0%	0.0%				
Hay	0.0%	0.0%				
Oats	0.0%	0.0%				
Potato	0.0%	0.0%				
Rye	0.0%	0.0%				
Soybean	0.0%	0.0%				
Sugarbeet	0.0%	0.0%				
Sunflower	0.0%	0.0%				
Wheat	80.0%	86.7%				
No	orth Dako	ta				
Ag. Crop	Min (%)	Max (%)				
Barley	0.0%	50.0%				
Com	0.0%	95.9%				
Beans	0.0%	0.0%				
Flax	0.0%	0.0%				
Hay	0.0%	0.0%				
	0.0% 0.0%	0.0% 0.0%				
Hay						
Hay Oats	0.0%	0.0%				
Hay Oats Potato	0.0% 0.0%	0.0% 0.0%				
Hay Oats Potato Rye	0.0% 0.0% 0.0%	0.0% 0.0% 0.0%				
Hay Oats Potato Rye Soybean	0.0% 0.0% 0.0% 0.0%	0.0% 0.0% 0.0% 0.0%				

NOTES: North Dakota irrigated crop data for 1997 was obtained from the USDA National Agricultural Statistics Service Minnesota irrigated crops were assumed to be limited to barley, corn and wheat.

Table 5-9

Percent of Livestock Raised

	Minimum	Maximum
Cattle	52.9	100
Sheep	0	14.8
Hogs	0	47
Poultry	N/A	N/A

Table 5-10
Soil Types within 1 Mile of Permitted Users

	Soil Types (Acres)						
River Reach by County	A/D	Α	В	С	CD	D	Total Acreage
		Red Rive	of the N	orth			
Emerson to Drayton	ŀ						
Pembina				2,829	1,492		4,321
Kittson				910			910
Drayton to Oslo			i				
Kittson				675			675
Marshall			949	2,656			3,605
Pembina				553	769		. 1,322
Walsh				5,260	1,819		7,079
Oslo to Grandforks							
Grand Forks			334	5,526	3,241		9,100
Marshall			421	818	3,241		1,239
Polk			5,269	2,641	150		8,059
Walsh				249			249
Count Fortes to Holatad							
Grand Forks to Halstad	i		4=0		40.044		
Grand Forks Norman			459	82	12,214	717	12,673 799
Polk			18,637	02	1,014	/1/	19,651
Traill			353	1,106	3,932	94	5,486
		Sheye	nne Rive	r			
Junction to Kindred							
Cass			5,420	4,021		3,011	12,452
Mindred As Lieber							
Kindred to Lisbon Ransom		2,810	15,240		1 404		10.474
nalisolii		2,810	15,240		1,424		19,474
Lisbon to Valley City							
Barnes			270		1,380	6,837	8,488
Ransom			5,463	1,683		5,551	7,146
L							
Valley City to Cooperstown							
Barnes	220		1,867		1,511	5,490	9,088
Cooperstown to Outlet							
Eddy			541		145	1,313	2,000
Griggs			201		143	1,313	2,000
Nelson			2,183			3,435	5,618
Total Acreage	220	2,810	57,608	29.008	29,092	21,077	139,816

NOTES:

Based on STATSGO soils database
Soil type A/D was grouped with soil type A.
Soil type C/D was grouped with soil type D.

Table 5-11 Deep Aquifers

Reach	Aquifer	Typical Water Quality	Typical Water Yield
6 through 10 Emerson	Dakota	Mean TDS 4,400 mg/L	<2 gpm
to Junction	Red River- Winnipeg	TDS 5,000-60,000 mg/L Sodium 13,000-16,000 mg/L Chloride 22,000-29,000 mg/L	Up to 500 gpm
5 Junction to Kindred	Dakota	TDS 2,680-4,060 mg/L High Sodium High Chloride High Sulfate	Some <50 gpm Most <5 gpm
4 Dakota Kindred to Lisbon		TDS 2,170-3,340 mg/L Mean TDS 880 mg/L Hardness 46-810 mg/L Mean Hardness 140 mg/L High Sodium High Chloride High Sulfate	<10 gpm
	Pierre	N.A.	N.A.
3 Lisbon to Valley City	Dakota	TDS N.A. High Sodium High Chloride High Sulfate	<10 gpm
	Pierre	TDS N.A. High Sodium High Chloride High Sulfate	<5 gpm
2 Valley City to Cooperstown	Dakota	TDS N.A. High Sodium High Chloride High Sulfate	<10 gpm
	Pierre	TDS N.A. High Sodium High Chloride High Sulfate	<5 gpm
1 Cooperstown to Outlet	Dakota	TDS 2,960-5,190 mg/L Mean TDS 3,800 mg/L Chloride 581-1,510 mg/L Mean Chloride 1,350 mg/L	Up to 500 gpm
	Pierre	TDS 308-2,550 mg/L Median TDS 1,230 mg/L High Sodium High Chloride High Sulfate	<5 gpm

N.A. Not Available

Table 5-12 Glacial Aquifers

Reach	Aquifer	Typical Water Quality	Typical Water Yield
6 through 10 Emerson to Junction	None		
5 Junction to Kindred	West Fargo	Hardness 220 - 230 mg/L TDS 370 - 1560 mg/L	> 500 gpm
to randed	Sheyenne Delta	TDS 200-1150 mg/L Mean TDS 390 mg/L Hardness 170-410 mg/L	> 250 gpm Up to 1000 gpm in some areas
4 Kindred to Lisbon	Sheyenne Delta	TDS 200-1150 mg/L Mean TDS 390 mg/L Hardness 170-410 mg/L	> 250 gpm Up to 1000 gpm in some areas
3 Lisbon to Valley City	Sand Prairie	TDS 338-624 mg/L Mean TDS 436 mg/L Hardness 260-490 mg/L	Highly variable 40 gpm up to 900 gpm
2 Valley City to Cooperstown	McVille	TDS 450-2200 mg/L Hardness N.A.	Up to 500 gpm
1 Cooperstown to Outlet	McVille	TDS 450-2200 mg/L Hardness N.A.	Up to 500 gpm
	Spiritwood	TDS 315-1010 mg/L Mean TDS 656 mg/L Hardness 136-500 mg/L Mean Hardness 308 mg/L	>500 gpm
	Sheyenne Channel	N.A.	N.A.

N.A. Not Available

Water quality and yield values were obtained from North Dakota State Water Conservation Commission County Groundwater Studies and USGS reports on Minnesota aquifers. Canadian aquifers were not evaluated for this report.

Table 5-13

Perceived Devils Lake Outlet Operation Effects on Permitted Users

Type of Use	Public Concerns	Water Supply Options	Perceived Water Supply Costs
Irrigation			
Cemeteries	Plant kills	Well installation	Unknown
		Connect to city water	Unknown
Golf courses	Plant kills	Connect to city water	\$20,000/year (for an 18-hole course); \$10,000/year to \$12,000/year (Canadian) for a 9-hole course
Nursery	Plant kills	Well installation	
• Parks	Plant kills	Connect to city water	Minimal cost (assuming parks are city owned and city water is nearby)
Vegetables	Decreased productivity or plant kills	Dug out or well installation	\$0/dug-out to unknown costs
Berries			
Livestock watering	Loss in body weight	Unknown	Unknown
Fish Hatcheries	Fish kills and resulting recreational losses	None	N/A
Domestic (lawn watering)	N/A	Connect to city water	Unknown
		Well installation	Unknown

Table 5-14
Reaches that Exceed the TDS Threshold Levels for Agricultural Crops
(referenced between trace data stations)

TRACE #	With Outlet					
6262	2					
CROPS	Soil Type A Soil Type B Soil Type C		Soil Type D			
Barley	NE	NE	NE	NE		
Corn	NE	NE	Outlet to Lisbon	Outlet to Junction		
Dry Edible Beans	Outlet to Kindred	Outlet to Junction	Outlet to Grand Forks	Outlet to Emerson		
Flax	NE	NE	Outlet to Lisbon	Outlet to Junction		
Hay*	NE	NE	NE	NE		
Oats	N/A	N/A	N/A	N/A_		
Potato	NE	NE	Outlet to Lisbon	Outlet to Junction		
Rye	NE	NE	NE	NE		
Soybean	NE	NE	NE	NE		
Sugarbeet	NE	NE	NE	NE		
Sunflower	N/A	N/A N/A N/A		N/A		
Wheat	NE	NE	NE	NE		
:	Without Outlet					
CROPS	Soil Type A	Soil Type B	Soil Type C	Soil Type D		
Barley	NE	NE	NE	NE		
Corn	NE	NE	NE	Outlet to Valley City		
Dry Edible Beans	NE	Outlet to Valley City	Outlet to Junction	Outlet to Grand Forks		
Flax	NE	NE	NE	Outlet to Valley City		
Hay*	NE	NE NE		NE		
Oats	N/A	N/A	N/A	N/A		
Potato	NE	NE	NE	Outlet to Valley City		
Rye	NE	NE	NE NE			
Soybean	NE	NE	NE	NE		
Sugarbeet	NE	NE	NE	NE		
Sunflower	N/A	N/A	N/A	N/A		
Wheat	NE	NE	NE	NE		

Notes: This table is based on trace 6262 and the average threshold levels by soil type.

Exceedance of threshold levels between Emerson and Lake Winnipeg was not evaluated.

NE indicates "No Effect"

N/A indicates information was not available for that crop.

^{*} Barley Hay

Table 5-15 Reaches that Exceed the TDS Threshold Levels for Cultivated Plants (referenced between trace data stations)

TRACE # 6262	RACE # With Outlet				
PLANTS	Soil Type A	Soil Type B	Soll Type C	Soil Type D	
Beans	Outlet to Kindred	Outlet to Junction	Outlet to Grand Forks	Outlet to Emerson	
Beets	NE	NE	NE	NE	
Broccoli	NE	NE	NE	NE	
Cabbage	NE	NE	Outlet to Valley City	Outlet to Junction	
Cantaloupe	NE	NE	NE	Outlet to Lisbon	
Carrot	Outlet to Kindred	Outlet to Junction	Outlet to Grand Forks	Outlet to Emerson	
Cucumber	NE	NE	NE	Outlet to Valley City	
Lettuce	NE	Outlet to Valley City	Outlet to Junction	Outlet to Grand Forks	
Onion	Outlet to Valley City	Outlet to Kindred	Outlet to Haistad	Outlet to Grand Forks	
Pepper	NE	Outlet to Valley City	Outlet to Junction	Outlet to Grand Forks	
Radish	Outlet to Valley City	Outlet to Kindred	Outlet to Halstad	Outlet to Grand Forks	
Spinach	NE	NE	Outlet to Valley City	Outlet to Kindred	
Sweet Com	NE	NE	Outlet to Lisbon	Outlet to Junction	
Sweet Potato	NE	Outlet to Valley City	Outlet to Junction	Outlet to Grand Forks	
Tomato	NE	NE	NE	Outlet to Valley City	
Apple, pear	NE	NE	Outlet to Lisbon	Outlet to Junction	
Grape	NE	NE	Outlet to Valley City	Outlet to Junction	
Strawberry	Outlet to Kindred	Outlet to Junction	Outlet to Grand Forks	Outlet to Emerson	
Plum	NE	Outlet to Valley City	Outlet to Junction	Outlet to Grand Forks	
Blackberry	NE	Outlet to Valley City	Outlet to Junction	Outlet to Grand Forks	
Boysenberry	NE	Outlet to Valley City	Outlet to Junction	Outlet to Grand Forks	
Raspberry	Outlet to Kindred	Outlet to Junction	Outlet to Grand Forks	Outlet to Emerson	
	kan sakali saka		andress.	# 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
PLANTS	Soil Type A	Soil Type B	Soil Type C	Soil Type D	
Beans	NE	Outlet to Valley City	Outlet to Junction	Outlet to Grand Forks	
Beets					
D6619	NE NE	NE	NE	NE.	
Broccoli			NE NE		
Broccoli	NE NE	NE NE	NE	NE NE	
Broccoli Cabbage	NE	NE		NE.	
Broccoli Cabbage Cantaloupe	NE NE NE	NE NE NE	NE NE NE	NE NE Outlet to Valley City NE	
Broccoli Cabbage	NE NE NE NE	NE NE NE	NE NE	NE NE Outlet to Valley City	
Broccoli Cabbage Cantaloupe Carrot	NE NE NE NE NE	NE NE NE NE Outlet to Valley City	NE NE NE Outlet to Junction NE	NE NE Outlet to Valley City NE Outlet to Grand Forks	
Broccoli Cabbage Cantaloupe Carrot Cucumber	NE NE NE NE NE NE	NE NE NE NE Outlet to Valley City NE	NE NE Outlet to Junction NE Outlet to Valley City	NE NE Outlet to Valley City NE Outlet to Grand Forks NE	
Broccoli Cabbage Cantaloupe Carrot Cucumber Lettuce Onion	NE	NE NE NE NE Outlet to Valley City NE NE	NE NE NE Outlet to Junction NE Outlet to Valley City Outlet to Valley City	NE NE Outlet to Valley City NE Outlet to Grand Forks NE Outlet to Junction Outlet to Halstad	
Broccoli Cabbage Cantaloupe Carrot Cucumber Lettuce	NE N	NE NE NE NE Outlet to Valley City NE NE NE	NE NE NE Outlet to Junction NE Outlet to Valley City Outlet to Valley City Outlet to Valley City	NE NE Outlet to Valley City NE Outlet to Grand Forks NE Outlet to Junction Outlet to Halstad Outlet to Junction	
Broccoli Cabbage Cantaloupe Carrot Cucumber Lettuce Onion Pepper	NE N	NE NE NE NE Outlet to Valley City NE NE NE NE NE	NE NE NE Outlet to Junction NE Outlet to Valley City Outlet to Valley City	NE NE Outlet to Valley City NE Outlet to Grand Forks NE Outlet to Junction Outlet to Halstad Outlet to Halstad Outlet to Halstad	
Broccoli Cabbage Cantaloupe Carrot Cucumber Lettuce Onion Pepper Radish Spinach	NE N	NE NE NE NE Outlet to Valley City NE NE NE NE NE NE NE NE	NE NE Outlet to Junction NE Outlet to Valley City Outlet to Valley City Outlet to Valley City Outlet to Valley City	NE NE Outlet to Valley City NE Outlet to Grand Forks NE Outlet to Junction Outlet to Halstad Outlet to Halstad Outlet to Halstad Outlet to Valley City	
Broccoli Cabbage Cantaloupe Carrot Cucumber Lettuce Onion Pepper Radish	NE N	NE NE NE Outlet to Valley City NE	NE NE Outlet to Junction NE Outlet to Valley City Outlet to Valley City Outlet to Valley City Outlet to Valley City NE NE	NE NE Outlet to Valley City NE Outlet to Grand Forks NE Outlet to Junction Outlet to Halstad Outlet to Halstad Outlet to Halstad Outlet to Valley City Outlet to Valley City	
Broccoli Cabbage Cantaloupe Carrot Cucumber Lettuce Onion Pepper Radish Spinach Sweet Corn	NE	NE NE NE Outlet to Valley City NE	NE NE Outlet to Junction NE Outlet to Valley City Outlet to Valley City Outlet to Valley City Outlet to Valley City NE NE Outlet to Valley City	NE NE Outlet to Valley City NE Outlet to Grand Forks NE Outlet to Junction Outlet to Halstad Outlet to Halstad Outlet to Halstad Outlet to Valley City Outlet to Valley City Outlet to Junction	
Broccoli Cabbage Cantaloupe Carrot Cucumber Lettuce Onion Pepper Radish Spinach Sweet Corn Sweet Potato	NE N	NE NE NE Outlet to Valley City NE	NE NE Outlet to Junction NE Outlet to Valley City Outlet to Valley City Outlet to Valley City Outlet to Valley City NE NE	NE NE Outlet to Valley City NE Outlet to Grand Forks NE Outlet to Junction Outlet to Halstad Outlet to Halstad Outlet to Halstad Outlet to Valley City Outlet to Valley City Outlet to Junction NE	
Broccoli Cabbage Cantaloupe Carrot Cucumber Lettuce Onion Pepper Radish Spinach Sweet Corn Sweet Potato Tomato	NE	NE NE NE NE Outlet to Valley City NE	NE NE NE Outlet to Junction NE Outlet to Valley City Outlet to Valley City Outlet to Valley City Outlet to Valley City NE NE Outlet to Valley City NE NE NE NE	NE NE Outlet to Valley City NE Outlet to Grand Forks NE Outlet to Junction Outlet to Halstad Outlet to Junction Outlet to Halstad Outlet to Valley City Outlet to Valley City Outlet to Junction NE Outlet to Valley City	
Broccoli Cabbage Cantaloupe Carrot Cucumber Lettuce Onion Pepper Radish Spinach Sweet Corn Sweet Potato Tomato Apple, pear Grape	NE	NE NE NE NE Outlet to Valley City NE	NE NE NE Outlet to Junction NE Outlet to Valley City Outlet to Valley City Outlet to Valley City Outlet to Valley City NE NE NE NE NE NE NE NE NE	NE NE Outlet to Valley City NE Outlet to Grand Forks NE Outlet to Junction Outlet to Halstad Outlet to Junction Outlet to Halstad Outlet to Valley City Outlet to Valley City Outlet to Junction NE Outlet to Valley City Outlet to Valley City	
Broccoli Cabbage Cantaloupe Carrot Cucumber Lettuce Onion Pepper Radish Spinach Sweet Corn Sweet Potato Tomato Apple, pear	NE	NE NE NE NE Outlet to Valley City NE	NE NE NE Outlet to Junction NE Outlet to Valley City Outlet to Valley City Outlet to Valley City Outlet to Valley City NE NE NE NE NE NE NE NE NE Outlet to Valley City NE NE Outlet to Valley City NE NE Outlet to Valley City	NE NE Outlet to Valley City NE Outlet to Grand Forks NE Outlet to Junction Outlet to Halstad Outlet to Junction Outlet to Halstad Outlet to Valley City Outlet to Valley City Outlet to Junction NE Outlet to Valley City	
Broccoli Cabbage Cantaloupe Carrot Cucumber Lettuce Onion Pepper Radish Spinach Sweet Corn Sweet Potato Tomato Apple, pear Grape Strawberry Plum	NE	NE NE NE NE Outlet to Valley City NE	NE NE NE Outlet to Junction NE Outlet to Valley City Outlet to Valley City Outlet to Valley City Outlet to Valley City NE NE NE NE NE NE Outlet to Valley City NE NE Outlet to Valley City Outlet to Valley City Outlet to Valley City Outlet to Valley City NE NE Outlet to Junction Outlet to Valley City	NE NE Outlet to Valley City NE Outlet to Grand Forks NE Outlet to Junction Outlet to Halstad Outlet to Junction Outlet to Halstad Outlet to Valley City Outlet to Grand Forks Outlet to Junction	
Broccoli Cabbage Cantaloupe Carrot Cucumber Lettuce Onion Pepper Radish Spinach Sweet Corn Sweet Potato Tomato Apple, pear Grape Strawberry	NE	NE NE NE NE Outlet to Valley City NE	NE NE NE Outlet to Junction NE Outlet to Valley City Outlet to Valley City Outlet to Valley City Outlet to Valley City NE NE NE NE NE NE NE NE NE Outlet to Valley City NE NE Outlet to Valley City NE NE Outlet to Valley City	NE NE Outlet to Valley City NE Outlet to Grand Forks NE Outlet to Junction Outlet to Halstad Outlet to Halstad Outlet to Halstad Outlet to Valley City Outlet to Valley City Outlet to Junction NE Outlet to Valley City	

Note: This table is based on trace 6262 and the average threshold levels by soil type.

Exceedance of threshold levels between Emerson and Lake Winnipeg was not evaluated.

NE indicates "No Effect"

Table 5-16

Potentially Affected Agricultural Crop Acreage

River Reach	Potentially Affected Agricultural Crop	Total Acres of Crops Grown	Acres of Potentially Affected Crops Based on Threshold Level and Soil Types With Outlet	Acres of Potentially Affected Crops Based on Threshold Level and Soil Types Without Outlet
RED RIVER OF THE NORTH		<u> </u>		
Lake Winnipeg to Emerson	Corn Wheat	N/A N/A N/A	0	0
Emerson to Drayton	Corn Wheat	1,914 2,392	0	0 0
Drayton to Oslo	Corn	3,349	0	0
	Wheat	5,504	0	0
Oslo to Grand Forks	Corn	5,161	0	0
	Wheat	7,723	0	0
Grand Forks to Halstad	Corn Wheat	7,451 16,849	6,377 0	0
Subtotal	Corn	17,874	6,377	0
Red River of the North	Wheat	32,468	0	
SHEYENNE RIVER	·			
Junction to Kindred	Corn	10,329	5,833	2,498
	Wheat	849	0	0
Kindred to Lisbon	Corn	12,463	911	911
	Wheat	538	0	0
Lisbon to Valley City	Corn	9,334	5,686	4,609
	Wheat	1,149	0	0
Valley City to Cooperstown	Corn	5,097	3,926	3,926
	Wheat	1,019	0	0
Cooperstown to Proposed Outlet	Corn	3,058	1,972	1,972
	Wheat	2,112	0	0
Subotal	Corn	40,281	18,329	13,916
Sheyenne River	Wheat	5,668	0	0
Total All Reaches	Corn Wheat	58,156 38,136	24,706 0	13,916 0

N/A - Location of permitted users in Manitoba was not available, and is not included in this table.

6.1 Purpose and Scope

This portion of the study identified the perceived effects of pumping Devils Lake water into the Sheyenne River and Red River of the North for non-permitted water users. The purpose for investigating non-permitted water users was to evaluate the public concerns relating to water quality changes in the Sheyenne River and the Red River of the North. Only the non-permitted river water users downstream of the proposed Devils Lake outlet were considered in this investigation. The potential effects on these river water users were not directly analyzed, although the types of uses are similar for permitted users and the potential effects can be found in Section 5.

For purposes of this investigation, the non-permitted river water users were identified by river reach. The five reaches, as defined in the project scope, were:

- 1. Upper Sheyenne River: From the proposed Devils Lake outlet's discharge point at Peterson Coulee to the north end of Lake Ashtabula.
- 2. Lake Ashtabula: The portion of the Sheyenne River (as it flows from north to south) through Lake Ashtabula.
- 3. Lower Sheyenne River: From Baldhill Dam (at the south end of Lake Ashtabula) to the Sheyenne River's confluence with the Red River of the North.
- 4. Red River of the North Urban: All portions of the Red River of the North (downstream of its confluence with the Sheyenne River) within the limits of cities and towns along its banks.
- 5. Red River of the North Rural: All portions of the Red River of the North (downstream of its confluence with the Sheyenne River) not within the limits of cities and towns along its banks.

Data regarding non-permitted river water use were gathered through telephone interviews. Interviews were conducted with five users per river reach, for a total of 25 non-permitted river water users. The types and frequency of use and the perceived potential effects of the with-outlet river water quality were requested from the non-permitted users contacted.

Based on the information garnered through interviews with non-permitted users, the potential damages, typical costs, and frequency of use were summarized for non-permitted water users.

6.2 Methodology

For this study, non-permitted water users were defined as river water users that were not listed as holding a permit from North Dakota, Minnesota, or Manitoba. In North Dakota, non-permitted users would include water users irrigating less than one acre, or withdrawing less than 12.5 acrefeet of water per year (approximately 11,000 gallons per day) from the river. In Minnesota, included would be those users whose daily water withdrawal is less than 10,000 gallons per day or who withdraw water for domestic use serving less than 25 people. Non-permitted users for the Canadian reach of the Red River of the North would include those river users who withdraw less than 5,000 imperial gallons per day (approximately 6,000 U.S. gallons per day), based on Manitoba's permit requirements.

As a consequence of their low volume and sporadic use, non-permitted users of river water are not registered with any government agency. Therefore, no listing of non-permitted users was available from local, State, or Federal agencies. As a result, a major task for this portion of the study was to identify and locate the Red River of the North and Sheyenne River non-permitted users in order to be able to contact them.

After contact was made, information from the individual interviews was recorded. The interview data were later tabulated and summarized to allow better characterization of non-permitted use. Several types of non-permitted uses were identified as a result of the interviews, but it should be noted that uses other than those identified are possible because only a sample of the non-permitted users were contacted for this study.

6.2.1 Identifying Users and Characterizing Uses

Eighteen governmental agencies and public organizations were contacted in the preliminary work of identifying and characterizing non-permitted users. Personnel at these agencies were interviewed to gain information as to the potential types of non-permitted users, the likely concerns of such users, and, if possible, names and phone numbers of non-permitted users. Table 6-1 lists the organizations that were contacted in collecting preliminary non-permitted user information.

Few of the agencies were actually able to characterize uses and identify non-permitted users. Therefore, other means of identification were required. Three different methods were used to identify users, depending on the location and availability of information:

- ! Use of county plat maps.
- ! Contacts with lake associations.
- ! Contacting community officials, use of local street maps, and use of personal contacts.

The approach that was used to identify individuals in the Upper Sheyenne, Lake Ashtabula, Lower Sheyenne, and Red River of the North rural river reaches involved use of county plat maps. (Plat maps do not identify land owners within urban zones; therefore, plat maps were not helpful in identifying non-permitted users for the Red River of the North urban reach.) Plat maps were obtained from Farm & Home Publishers and Midland Atlas Company for the following North Dakota and Minnesota counties:

- ! Midland Atlas Company
 - Ransom, ND
 - Richland, ND
 - Sargent, ND
- ! Farm & Home Publishers
 - Kittson, MN
 - Marshall, MN
 - Polk, MN
 - Barnes, ND
 - Cass, ND
 - Grand Forks, ND
 - Griggs, ND
 - Nelson, ND
 - Pembina, ND
 - Steele, ND
 - Traill. ND
 - Walsh, ND

The townships adjacent to the Sheyenne River and the Red River of the North were examined on the plat maps, and residents living within approximately ¼ mile were identified for each river reach. These potential non-permitted users were compared to the list of known permitted users to minimize contact duplication. Those who were not permit holders were listed and contacted as potential interviewees. If the person contacted was not a river water user, the next person on the list was contacted. This procedure continued until five individuals per river reach had been interviewed or until the list of potential non-permitted users was exhausted. This method was sufficient to identify the five required non-permitted users for the Upper Sheyenne, Lower Sheyenne, and Red River of the North rural river reaches.

The plat map method was insufficient to identify the required non-permitted users for the Lake Ashtabula river reach. The Barnes County Registrar of Deeds was contacted and the phone number for a member of the Lake Ashtabula Lake Association was obtained. The lake association contact provided the names of several individuals who use Lake Ashtabula water. Using the names provided, the five required non-permitted user interviews for the Lake Ashtabula reach were completed.

Identifying five non-permitted users in the Red River of the North urban reach proved to be extremely difficult. As previously mentioned, agency contacts and plat maps did not provide help in identifying users in this reach., Therefore, various other methods were attempted to locate individuals in the Red River of the North urban river reach. After locating the towns and municipalities along the Red River of the North, telephone calls were placed to staff at town halls and city officials. Few of these calls were answered or returned, and those contacted were typically unable to provide the names of non-permitted users. Adding to the difficulty was that throughout the process, contacts were often reluctant to divulge the names of non-permitted users for fear of a regulatory agency identifying those users as permit violators or as someone actually requiring a permit (even though their limited use may not require a permit).

In another approach, city maps were obtained and the streets along the Red River of the North were identified. Using the street names, residents living on those streets were identified by looking them up using a "reverse" telephone directory. This method was also generally unsuccessful.

Several Barr Engineering Company employees volunteered the names of friends and relatives living in Red River of the North urban areas, but those contacted proved to not actually be non-permitted users. Despite the very limited success rate for each of these methods, the combination of these

efforts eventually produced sufficient contacts to complete the required five Red River of the North urban non-permitted user interviews.

Interviewing Process

Telephone calls were placed at various times throughout the typical work day and in the evening. If the individuals were not contacted on the first call, a brief message was left explaining the purpose of the call, the information needed, and a toll-free number for the person to call back with the best time to contact them. If the individual failed to call back within 2 days, another call was placed. If the second call failed to contact the potential non-permitted user, a second message was left. If the second message failed to produce results, the individual was removed from the interview pool and the next person was called.

When a potential non-permitted user was contacted, the interview was conducted according to a fixed format. An introduction and a brief description of the study intentions was presented to the interviewee. The interviewee was then requested to participate by answering a few questions. The respondents were assured that the information gathered was for use in this study alone and that it was not the intent of this study to locate permit violators. Those contacts that declined to be interviewed were encouraged to take the opportunity to voice their opinions. If offered, these concerns were recorded.

For respondents who agreed to be interviewed, the first step was to confirm their use of the water from the Sheyenne/Red River of the North. If they were not in fact users, respondents were allowed to voice any concerns about the proposed Devils Lake outlet. If water use was confirmed, the respondent was asked the following questions:

- 1. What do you currently use the water for, or what have you used the water for in the past?
- 2. When do you use the water (which months or times of year)?
- 3. How much water would you say you withdraw (if known)?
- 4. Are you currently satisfied with the quality of the water you withdraw from the river?
- 5. How would you say a change in water quality would affect you? (For example, would you have damages to crops, livestock, or anything else?)
- 6. What would be your solution/response to the above-mentioned concerns? Can you quantify what it would cost?

6.2.2 Determination of Threshold Levels

The types of non-permitted river water uses identified through the selected interviews were similar to those identified for the permitted users. Table 6-2 lists the types of non-permitted uses identified. Threshold levels for most of these uses were determined and defined in Section 5.2.5 for permitted users. The only difference between the permitted and non-permitted users would be the annual water use.

Threshold levels for domestic (drinking water) use for non-permitted users would be similar to the primary drinking water standards identified for the water treatment facilities (Section 3.2.3).

Selected information on tolerance levels is included in Appendix G.

6.3 Results

6.3.1 Concerns of Water Users

A summary of the responses was prepared for each of the interviews with non-permitted users. These summaries, listed by river reach, are available for review in Appendix H.

Table 6-2 summarizes the interview responses by describing the various types of water usage and listing the associated periods of use. The seasonal timing and description of use summarizes the interview responses over all five river reaches.

Table 6-3 shows the number of non-permitted respondents that identified the various types of uses in each of the five river reaches. The total number of uses exceeds the 25 permittees that were interviewed because some of the non-permitted users utilize the water for more than one purpose. The types of uses are based only on the user interviews and are limited to those identified through the interview process. Other types of uses are likely but were not determined through this study.

About half of the non-permitted river water users (13 out of 25) expressed concern that a decrease in the water quality would force them to find an alternate water supply source. Several of the interviewees also expressed concern over the increase in water quantity, indicating that it may cause flooding problems. Five of the non-permitted river water users felt that there would be no affect by the decrease in water quality. Four of these indicated that they already had an alternative water supply. The remaining seven non-permitted users had no concerns with respect to the proposed outlet from Devils Lake and the potential decrease in water quality.

6.3.2 Potentially Affected Users

The number of potentially affected non-permitted river water users could not be computed because of the lack of data compiled on non-permitted river water users and quantities of use. Therefore, this section presents only general results for the different types of river water uses that were identified during the interview process. Much of the information in this section was taken from the detailed information presented for permitted river water users (Section 5.3.4). Table 6-4 lists the perceived effects of Devils Lake outlet operation on non-permitted users along with water supply options and approximate costs.

6.3.2.1 Domestic

Human ingestion of water with increased sulfates or TDS beyond the U.S. EPA's secondary standards (250 mg/L for sulfates and 500 mg/L for TDS) could potentially produce laxative effects. The Trace 6262 data indicates that the level of both sulfates and TDS would be exceeded along the entire reach.

6.3.2.2 Livestock

The assumed TDS threshold level of 1,000 mg/L for poultry is exceeded for the with-outlet Trace 6262 from the outlet to the confluence of the Sheyenne River and the Red River of the North. This threshold level is not exceeded by the without-outlet Trace 6262. The effects of exceeding the threshold level would be mild and temporary diarrhea or water droppings, which would likely have a greater effect on the young. The assumed TDS threshold level of 3,000 mg/L for all other livestock is not exceeded for the with-outlet Trace 6262.

The assumed sulfate threshold level of 350 mg/L for all livestock is exceeded for the with-outlet Trace 6262. The effects of exceeding the threshold level would be diarrhea or electrolyte imbalance in young animals (which may even cause death in rare cases). This sulfate level is reached in the with-outlet Trace 6262 between the outlet and the confluence of the Sheyenne River and the Red River of the North.

6.3.2.3 Lawns and Domestic Gardens

Based on Trace 6262 with-outlet data and threshold levels, there would be no effects for grasses used at golf courses or for watering lawns. Table 5-6 lists the relative salt tolerance for grasses and other cultivated plants.

For domestic gardens, the most sensitive cultivated plants (beans, carrots, onions, radishes, strawberries, and raspberries) would potentially be affected under existing without-outlet irrigation from the Devils Lake outlet to approximately Valley City for soil type A; affected to Emerson for soil type D. This would indicate that it is unlikely these crops are being successfully grown using river water for irrigation in low permeability soils along these river reaches. These sensitive plants would be affected along a longer reach for the increased with-outlet TDS concentrations from the Devils Lake outlet to Kindred for soil type A; affected reaches are also longer for these plants grown in soil types B and C.

Cabbage, lettuce, peppers, sweet potatoes, plums, blackberries, and boysenberries are less sensitive; affected for soil types C and D under without-outlet conditions. Under with-outlet conditions, the affected reaches are longer and there are more soil types affected for these plants.

Beets, Broccoli, Cantaloupe, cucumber, and tomato are not affected under any soil types under without-outlet conditions; most of these tolerant species would be affected by the with-outlet conditions (in the low permeability soil types). Of these tolerant species, beets are the only cultivated plants that would not affected by the Trace 6262 with-outlet conditions (under all soil types). Table 5-15 lists the trace data station reaches where potential effects on cultivated plants may be seen (based on Trace 6262 concentrations for both with-and without-outlet).

6.3.2.4 Vegetable Crops

Many of the vegetable crops are described with the domestic gardens above. In nearly all counties within the study area, wheat and corn are the most widely planted irrigated agricultural crops. Barley is the only other irrigated agricultural crop planted in this region. All other crops grown in the region are not listed as being irrigated (North Dakota Agricultural Statistics, 1998). Study results presented in Table 5-4 show that corn would be the only crop that would have the potential to be affected by the water quality data indicated in Trace 6262 during the growing season.

Table 5-14 lists the reaches in which the threshold levels for corn are exceeded for both with- and without-outlet conditions. Comparison of without-outlet Trace 6262 data with threshold levels indicates that corn yields would be affected under existing water quality conditions from the outlet to Valley City for clayey soils; corn grown in higher permeability soils would not be affected under existing conditions. For with-outlet Trace 6262 conditions, corn yields grown in clayey soils could be affected from the outlet to the Junction of the Sheyenne and Red Rivers; corn grown in low permeability soils (soil type C) could be affected from the outlet to Lisbon.

6.3.2.5 Trees and Shrubs

Detailed information on the salt tolerance of trees and shrubs was not available. Table 5-6 provides a relative salt tolerance for many trees and shrubs. There is a wide range of tolerance to salt concentrations; pines and maples are generally less tolerant and oaks and ashes are generally more tolerant (although the list of species is very sparse). Only non-tolerant species would potentially be affected by the Trace 6262 water quality TDS concentrations.

6.3.2.6 Recreational

Human ingestion of water with increased sulfates or TDS beyond the U.S. EPA's secondary standards (250 mg/L for sulfates and 500 mg/L for TDS) could potentially produce laxative effects. The Trace 6262 data indicates that the level of both sulfates and TDS would be exceeded along the entire reach.

6.3.3 Water Supply Alternatives and Costs

As identified in Section 5.2.7, the water supply options for the non-permitted users consist of the following:

- ! Well installation
- ! Rural water supply connection
- ! Well installation and supply for multiple users
- ! Withdrawal from tributary stream
- ! Reimbursement for damages

These water supply alternatives might not be technically or economically feasible for all non-permitted river water users because of the lack of groundwater, lack of tributary stream water, or distance to the nearest rural water service. The water supply alternatives would have to be developed on a case-by-case basis, depending on the location and alternatives available for each user. These alternatives and costs are discussed in detail in Section 5.3.5.

6.4 Discussion

6.4.1 Types of Use

As shown in Table 6-2, non-permitted water users are using the water from the rivers for a variety of activities. The identified uses include small farm use, home and commercial landscape watering, drinking, and recreation. Because of the difficulty locating non-permitted users for this study, it is expected that there are relatively few non-permitted users.

The relative percentage for each of the use types is shown in Table 6-3. Approximately 36 percent of the respondents used the water for livestock, 44 percent for garden watering, 48 percent for lawn watering, 8 percent for tree watering, 8 percent for domestic, 4 percent for recreation, and 8 percent for commercial gardening. (Because of the respondents using the water for more than one purpose, the percentages do not add to one hundred.) As a result of the limited sample size, the percentages of interviewees identifying the various uses cannot be expected to apply universally to all non-permitted users along the Sheyenne and Red River of the North. The information presented in Table 6-3 is limited to the interviewees' responses and, therefore, other possible non-permitted water uses might exist. Such uses may include crop irrigation, golf course irrigation, gravel washing operations, concrete fabrication, etc.

6.4.2 Timing of Use

Since most of the non-permitted use identified was related to plant production, water withdrawal occurs mainly during the spring and summer growing seasons (see Table 6-2). The exceptions are for domestic and livestock use (which occur throughout the entire year) and tree nursery operations (which continue through the fall). Therefore, any water changes resulting from the Devils Lake outlet would be expected to have the greatest impact on non-permitted users in the spring and summer months.

6.4.3 Water Quality Concerns and Water Supply Options Expressed by Users

The impacts that a water quality change would have on non-permitted users vary according to the type of use and the degree of reliance on the river water (quantity of use). Table 6-4 lists the perceived effects that a water quality change would have on non-permitted users, according to the type of use identified. Some non-permitted users (e.g., recreational) are likely to be essentially unaffected by water quality changes. It was frequently mentioned by the interviewees, however, that if water quality got excessively bad, users would consider connecting to the rural water system. Water supply alternatives and costs are described in Section 5.2.7.

6.4.3.1 Domestic

Only two non-permitted water user respondents would be considered domestic users. One of the users is located in the Red River of the North rural reach and the other in the Red River of the North urban reach. Both use the water as their primary drinking water source through the entire year. Only the Red River of the North rural domestic user felt a water quality change would have a significant impact. The Red River of the North urban domestic user (located in Manitoba) did not anticipate that a change in water quality would have a significant impact because the user currently does onsite treatment of the river water. The U.S. EPA secondary standard for sulfate and TDS are 250 mg/L and 500 mg/L, respectively. Since the sulfate and/or TDS water quality levels in Trace 6262 exceed the standards, laxative effects may be noticed and taste problems may develop. A water supply alternative suggested by the Red River of the North rural domestic user was connecting to the rural water system. Another alternative would be onsite treatment. Well installation would not be an option for most users because high-yield aquifers are scarce in this region (as described in Section 5.2.7).

6.4.3.2 Livestock

The quantity of use appears to vary considerably for non-permitted users that rely on the river water to supply livestock. Some of those interviewed reported using the water to supply a few head of cattle/sheep; others indicated that river water is used to supply an entire herd. Many of the respondents were unconcerned that a change in water quality might affect their livestock. However, the magnitude of the effects will be a function of the actual water quality change at the point of withdrawal. As discussed in Section 5.2.5.4, an increase in sulfates to levels greater than about 350 ppm (mg/L) can cause chronic diarrhea, electrolyte imbalance, lower milk fat percentage, and sometimes cause death in young animals. Poultry are also sensitive to TDS concentrations above 1,000 mg/L.

Since the water quality in Trace 6262 under with-outlet conditions exceeds these thresholds, non-permitted livestock watering users would have to consider alternative water sources. Interviewees felt there would be no feasible alternative water source. Water supply options for livestock watering would generally be limited to rural water connections. Well installation would not be an option for most users because high-yield aquifers are scarce in this region (described in Section 5.2.7). Table 6-4 lists the respondents' estimate of potential costs for installation of a new well. If no alternative source could be located, possible onsite treatment of the river water or monetary compensation for potential losses would need to be investigated.

6.4.3.3 Lawns and Domestic Gardens

Interviewees watering their residential lawns and gardens with river water did not anticipate that a change in water quality would have a significant impact on their water usage. If water quality deteriorated to the point that the water became unusable, they stated they would be forced to install a well or use the rural water system. Respondents thought that installing a well would cost approximately \$500 and connecting to rural water was about \$265 per year plus a per-gallon usage rate, as indicated in Table 6-4. However, the scarcity of high-yield aquifers would eliminate this option for most users (Section 5.2.7). As discussed in Section 6.3.2.3, the majority of the pasture and hay grasses are moderately tolerant to salinity. Therefore, a change in water quality should not affect the individuals watering their lawn, golf courses, or cemeteries.

6.4.3.4 Vegetable Crops

Most vegetable crops are moderately sensitive to salinity, as discussed in Section 6.3.2.4. Domestic and commercial irrigation of vegetables with salinity levels of 400 mg/L or greater could result in a reduction in crop yield, depending on the plant and soil type. Even without the outlet, the TDS levels in the Sheyenne and Red River of the North exceed this salinity level. The effects that a water quality change may have on vegetable production is dependent not only on the water quality of the river water but also the existing salinity of the soil. Commercial vegetable growers indicated a net income loss of \$100,000 to \$150,000 if the salinity levels have a severe impact on their crops. NDSU agronomists and soil specialists have examined the effects of salinity on crop production (Economics Database Update for the Lands and Developments, Feasibility Study, Devils Lake, North Dakota, Watts & Associates, October 1997). These data were not available in a format suitable for inclusion in this report. Other publications from the NDSU on soils and irrigation are included in Appendix G. Water supply alternatives presented by the respondents were to seek monetary compensation or install 6-inch to 12-inch diameter irrigation wells. However, the scarcity of high-yield aquifers would eliminate this option for most users (Section 5.2.7).

6.4.3.5 Trees and Shrubs

Only two non-permitted user interviewees mentioned the use of river water for tree and shrub watering. One of the interviewees represented a nursery that is irrigating approximately 90 acres of trees and shrubs. The respondents felt a change in water quality would adversely affect the trees, asserting that iron would be tied up in the soil and the tree leaves may turn yellow. This user could not quantify these or other potential damages caused by sulfate or TDS increases. The relative tolerance of selected cultivated plants is listed in Table 5-6. Potential water supply

alternatives that were mentioned include well installation, rural water connection, or withdrawal from a nearby creek. However, the scarcity of high-yield aquifers would eliminate this option for most users (Section 5.2.7).

6.4.3.6 Recreational

The one respondent using river water for recreational purposes withdraws water from Lake Ashtabula to fill a camp swimming pool. The interviewee did not foresee any negative impacts on using the water to fill the pool. However, human ingestion of the pool water with increased sulfates or TDS beyond the U.S. EPA's secondary standards could potentially produce laxative effects. Therefore, since sulfate and TDS levels in Trace 6262 exceed the secondary standards, an alternative water source (such as a rural water connection) should be considered.

6.4.3.7 Other

Several respondents had concerns about the effect that a change in water quality would have on wildlife. The potential effects on wildlife is beyond the scope of this investigation.

6.5 Summary

Even though the interview sample was limited to 25 respondents, a variety of uses were identified. Several of the respondents indicated multiple uses. Uses other than those identified in this survey are likely.

In conclusion, most of the interviewees are withdrawing water for lawn, garden, and livestock watering. A small percentage of those interviewed (8 percent) are using the water for domestic purposes, which includes drinking water. Potential water supply alternatives include doing nothing, rural water connection, city water connection, onsite treatment, and monetary compensation. Well installation would not be an option for most users because of the scarcity of high-yield aquifers in this region. Commercial fruit and vegetable growers estimate potential losses from \$5,000 to \$150,000 per year.

Section 6 Tables

Table 6-1	Organizations Contacted
Table 6-2	Types of Water Use
Table 6-3	Number of Interviewees by Type of Use
Table 6-4	Perceived Effects of Devils Lake Outlet Operation on Non-Permitted Users

Table 6-1

Organizations Contacted

Organization				
Minnesota Department of Natural Resources (MDNR)				
United States Geological Survey (USGS)				
North Dakota State University Agricultural Extension Service				
Red River of the North Conservation & Development Council				
North Dakota State Water Commission (NDSWC)				
North Dakota Department of Health				
North Dakota Environmental Health				
North Dakota State University Civil Engineering Department				
Manitoba Water Resources				
Bureau of Reclamation				
Pembina County				
Barnes County				
Minnesota Extension Service				
Barnes County Water Resource District				
Griggs County Water Resource District				
Cass County Water Resource District				
Red River of the North Water Management Consortium				
Agassiz Irrigation Association Inc.				
Minnesota Department of Health				

Table 6-2

Types of Non-Permitted Water Use

Type of Use	Description of Use	Seasonal Timing of Use	
Domestic	Water used as primary drinking water source and for all household activities.	Spring, Summer, Fall, and Winter	
Livestock	Watering cattle and/or sheep by pumping water from the river or by having pasture lands adjacent the river's edge.	Spring, Summer, Fall, and Winter	
Domestic Garden	Irrigation of domestic flowers and vegetables: tomatoes, peas, beans, sweet corn, etc.	Summer	
Lawns	Irrigation of private lawns and shrubbery.	Spring and Summer	
Trees and Shrubs	Irrigation of trees and shrubs: domestic and commercial.	Spring, Summer, and Fall	
Recreation	Water used to fill camp swimming pool.	Summer	
Commercial Gardeners	Irrigation of commercial fruit and vegetable crops, such as tomatoes, peppers, cucumbers, onions, strawberries, etc.	Spring and Summer	

Table 6-3

Number of Non-Permitted Interviewees by Type of Use

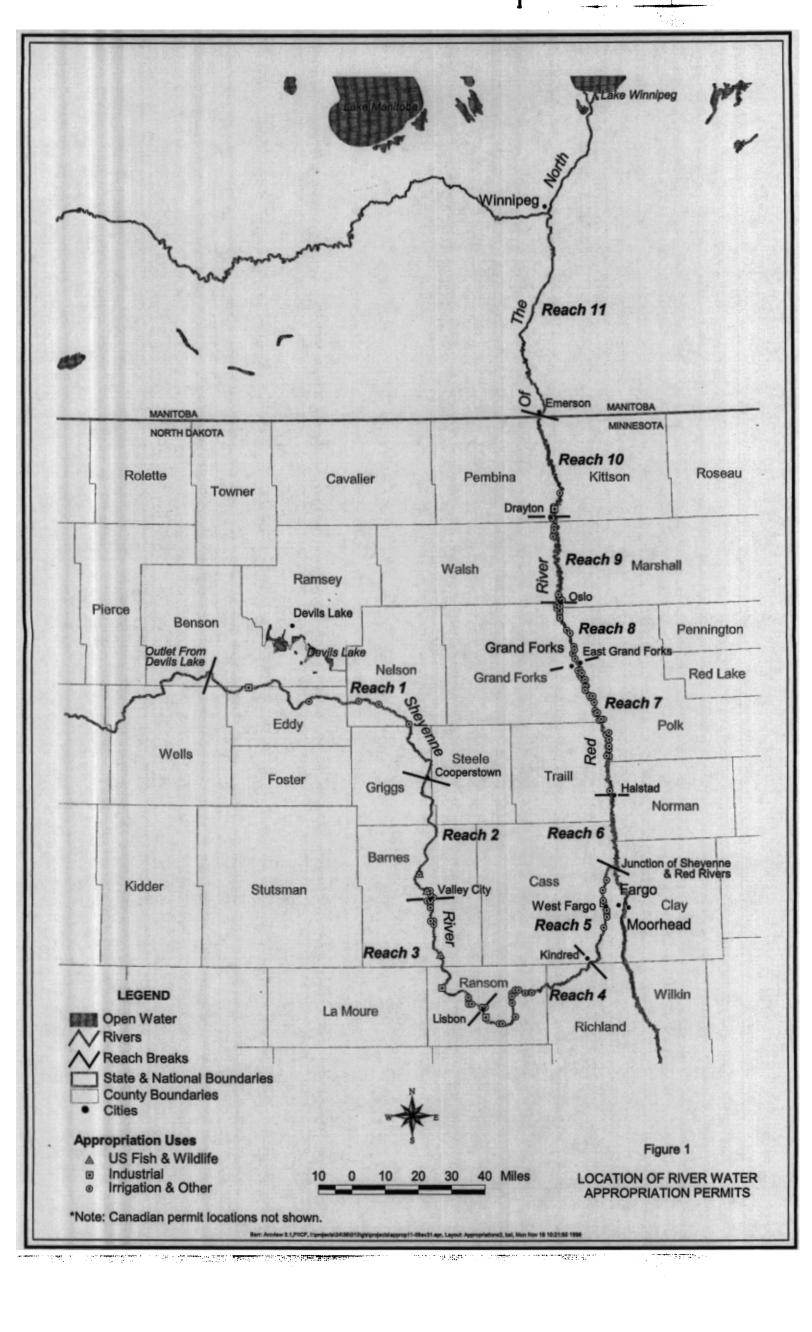
	Type of Use and Number of Respondents Identifying the Use						
River Reach	Domestic	Domestic Livestock Gardens Lawns Shrubs Gardens Recreation					Recreation
Upper Sheyenne		4	1	1			
Lake Ashtabula		1	3	3	1		1
Lower Sheyenne		3	3	4			
Red River of the North Urban	1		4	4			
Red River of the North Rural	1	1			1	2	
Total	2	9	11	12	2	2	1
Overall %*	8%	36%	44%	48%	8%	8%	4%

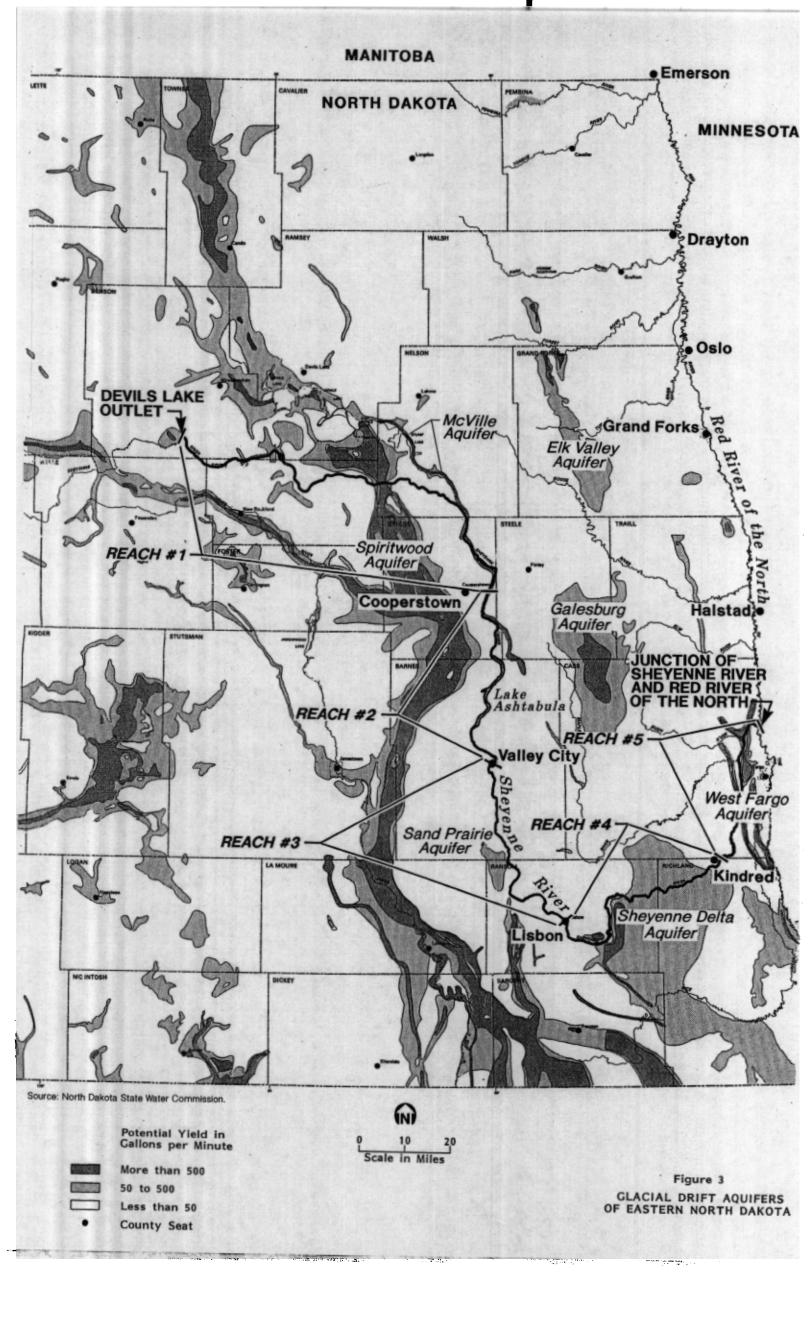
^{*} Overall % was based on the number of total permittees. Several permittees have multiple uses.

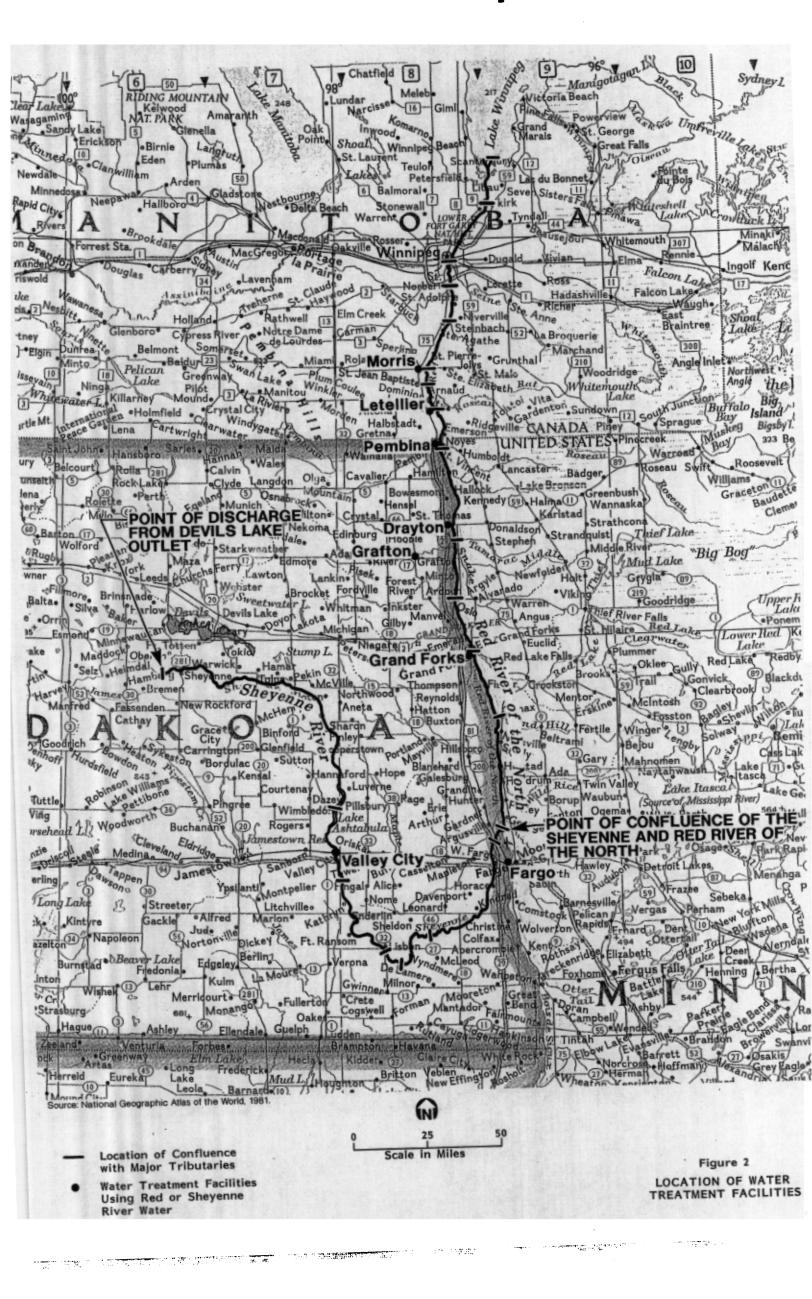
Table 6-4

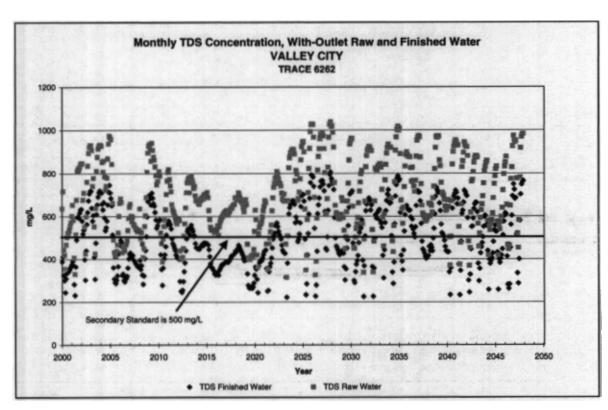
Perceived Effects of Devils Lake Outlet Operation on Non-Permitted Users

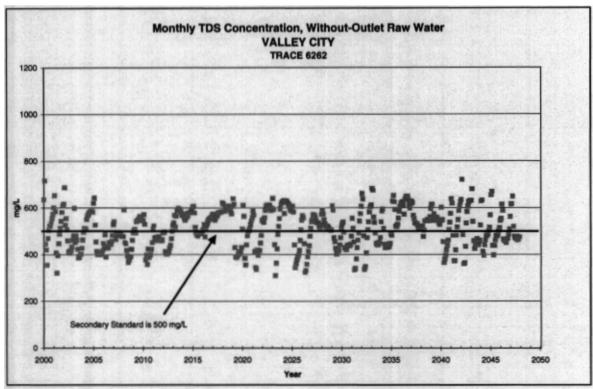
Type of Use	Stated Concern	Water Supply Options	Perceived Water Supply Costs		
Domestic	Human Consumption:	Rural Water Connection	Approx. \$265/year plus a per gallon cost		
	! Laxative Effects ! Taste Problems	City Water Connection	N/A		
	: Taste i Tobienis	Onsite Treatment	N/A		
Livestock	Loss in Body Weight	Well Installation	>\$500/well		
		Rural Water Connection	Approx. \$265/year plus a per gallon cost		
		Onsite Treatment	N/A		
		Do Nothing	N/A		
Domestic Garden	Decreased Productivity	Well Installation	Approx. \$500/well		
		Rural Water Connection	Approx. \$265/year plus a per gallon cos		
		Do Nothing	N/A		
Lawns	"Burn" Lawns	Well Installation	Approx. \$500/well		
		Rural Water Connection	Approx. \$265/year plus a per gallon cost		
		Do Nothing	N/A		
Trees and Shrubs	Decreased Growth or Tree Kills	Well Installation	Approx. \$500/well		
		Rural Water Connection	Approx. \$265/year plus a per gallon cost		
Recreation	Possible Human Consumption:	Well Installation	Approx. \$500/well		
(swimming pool)	! Laxative ! Taste	Rural Water Connection	Approx. \$265/year plus a per gallon cost		
	: 18516	Do Nothing	N/A		
Commercial Garden	Decreased Productivity or Plant Kills	Well Installation	\$500- \$35,000/well		
! Vegetables! Fruit	Vegetables Fruit		\$5,000 to \$150,000/year		







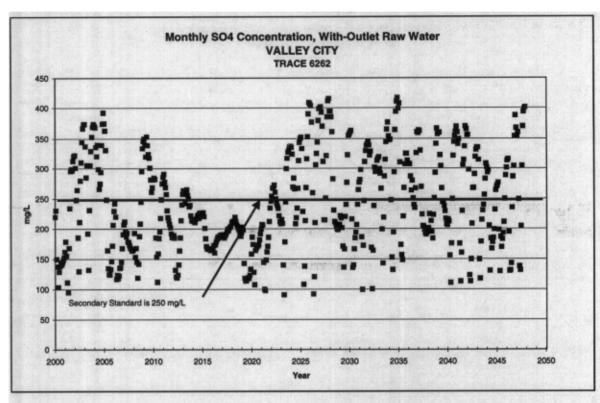


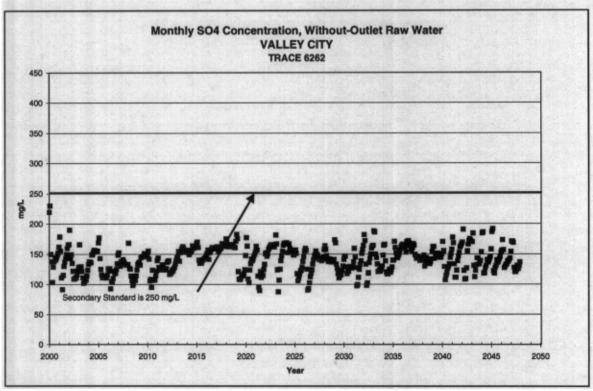


Notes: Finished water TDS concentration under without-outlet water treatment facility conditions was not modeled.

Current finished water TDS at this water treatment facility averages approximately 370 mg/l.

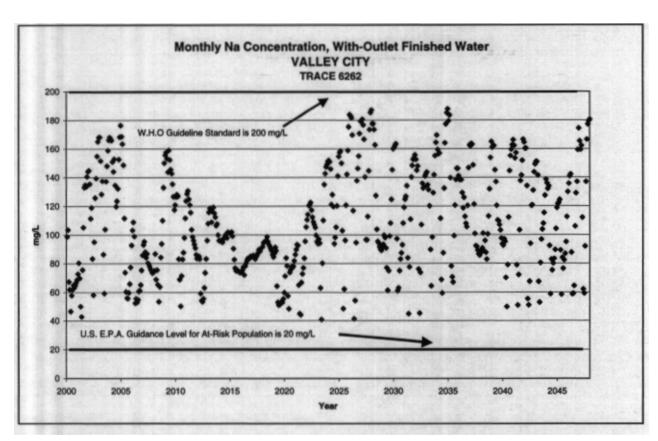
Trace data from Valley City.



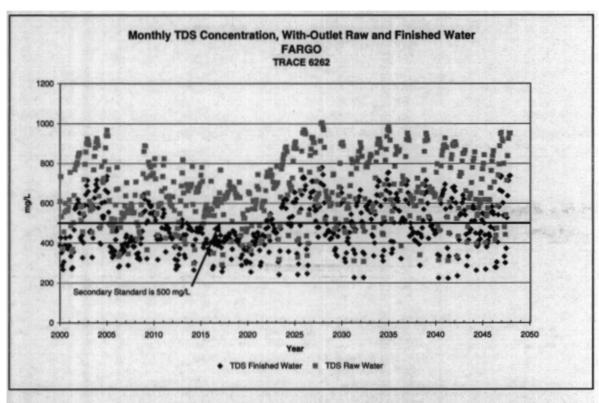


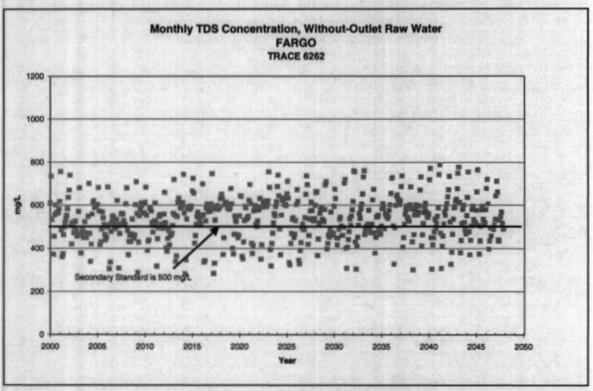
Notes: Based on data obtained from the water treatment facilities, it was assumed that the raw water SO4 concentrations would not be significantly affected by treatment.

Trace data from Valley City.



Notes: Trace data from Valley City.



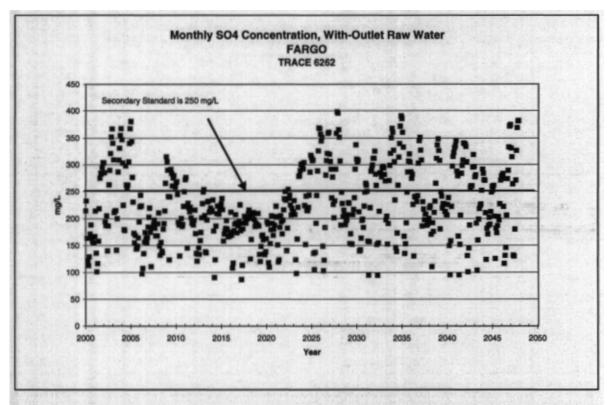


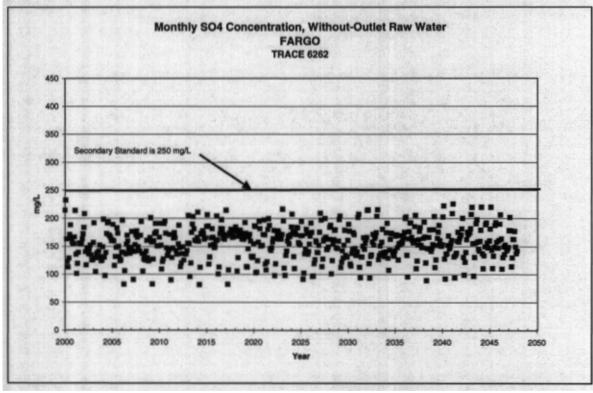
Notes: Finished water TDS concentration under without-outlet water treatment facility conditions was not modeled.

Current finished water TDS concentration at this water treatment facility was not available.

Trace data from Kindred.

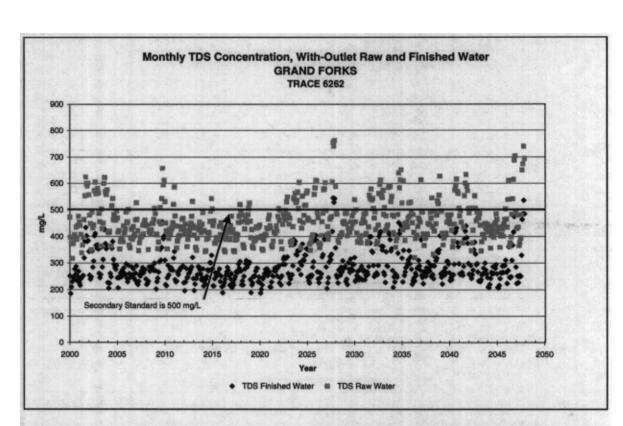


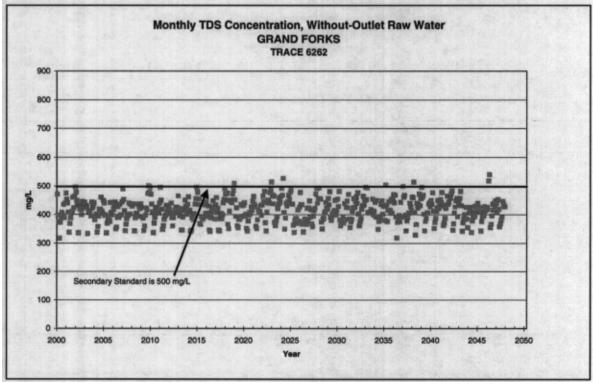




Notes: Based on data obtained from the water treatment facilities, it was assumed that the raw water SO4 concentrations would not be significantly affected by treatment.

Trace data from Kindred.



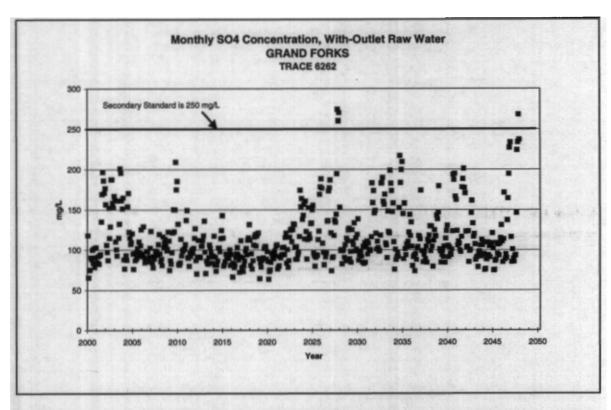


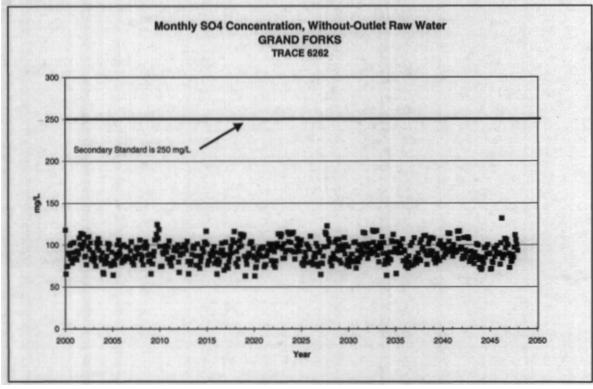
Notes: Finished water TDS concentration under without-outlet water treatment facility conditions was not modeled.

Current finished water TDS concentration at this water treatment facility averages approximately 250 mg/l.

Trace data from Halstad.



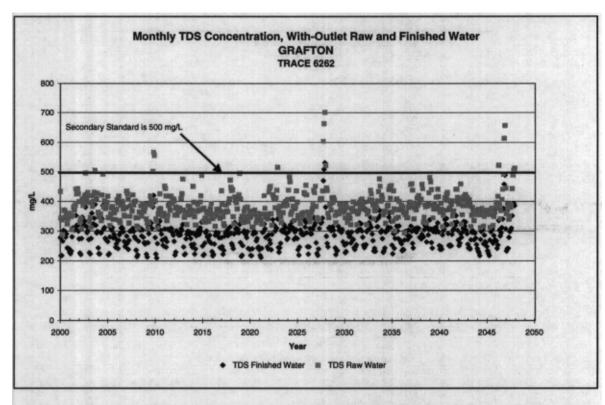


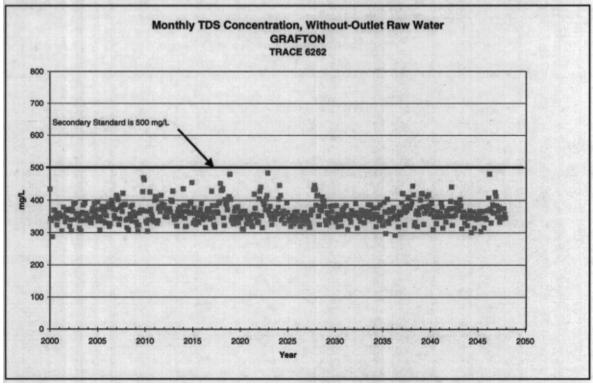


Notes: Based on data obtained from the water treatment facilities, it was assumed that the raw water SO4 concentrations would not be significantly affected by treatment.

Trace data from Halstad.



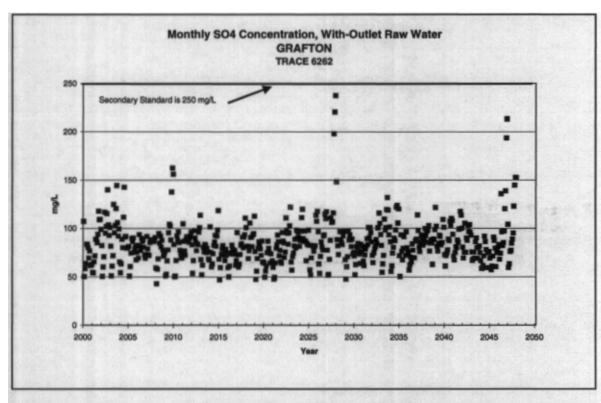


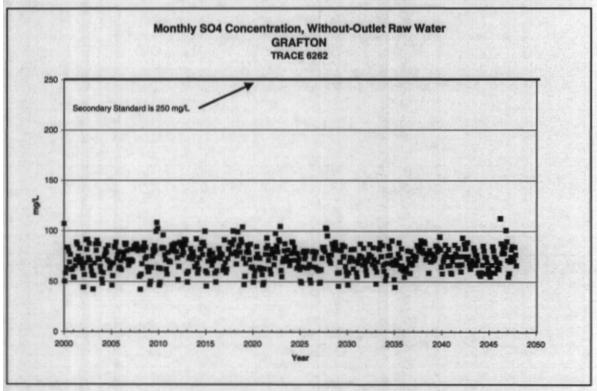


Notes: Finished water TDS concentration under without-outlet water treatment facility conditions was not modeled.

Current finished water TDS concentration at this water treatment facility averages approximately 300 mg/l.

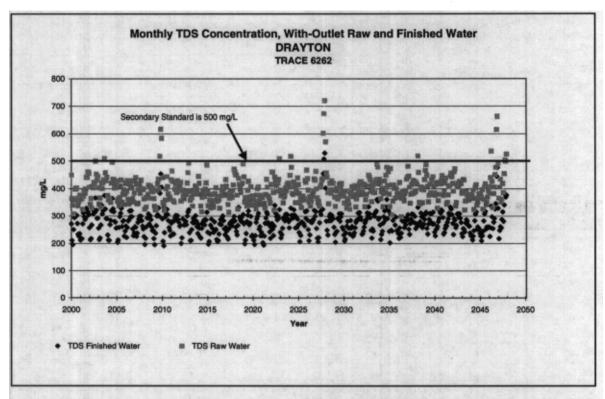
Trace data from Oslo.

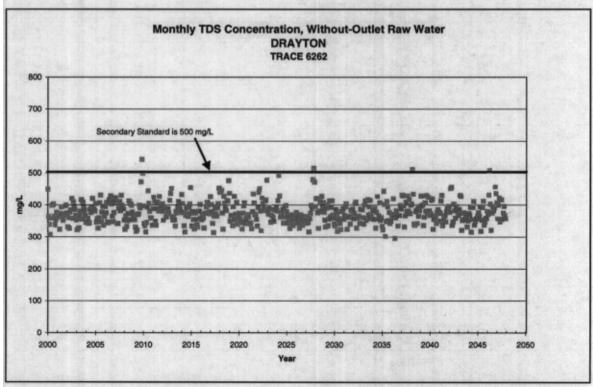




Notes: Based on data obtained from the water treatment facilities, it was assumed that the raw water SO4 concentrations would not be significantly affected by treatment.

Trace data from Oslo.



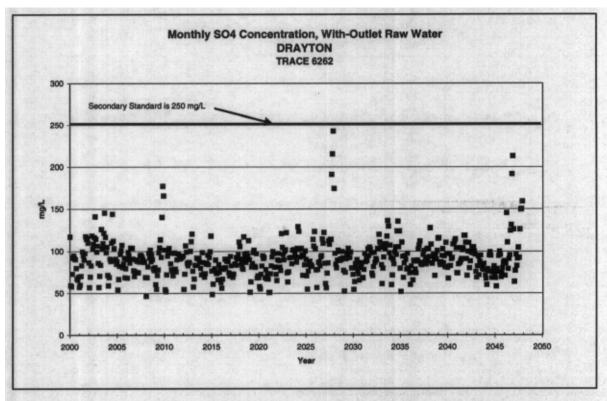


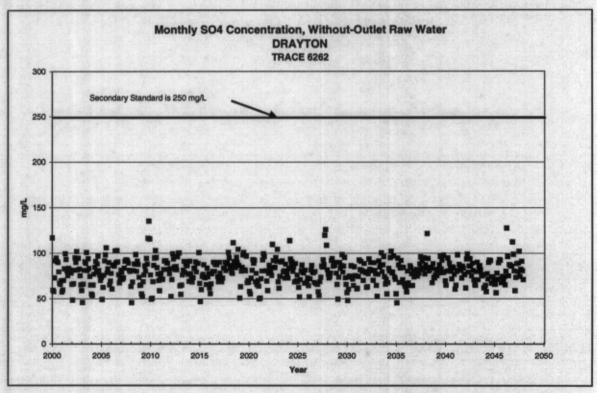
Notes: Finished water TDS concentration under without-outlet water treatment facility conditions was not modeled.

Current finished water TDS at this water treatment facility was not available.

Trace data from Drayton.



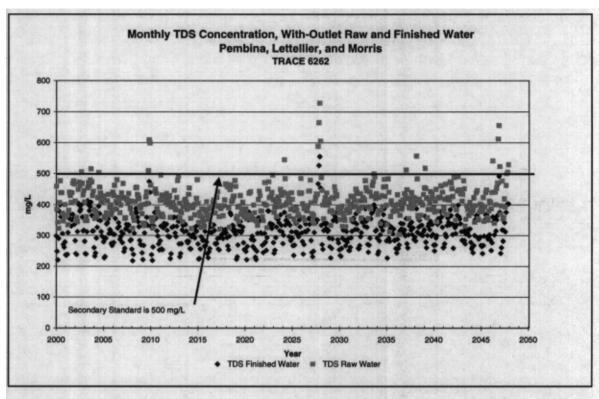


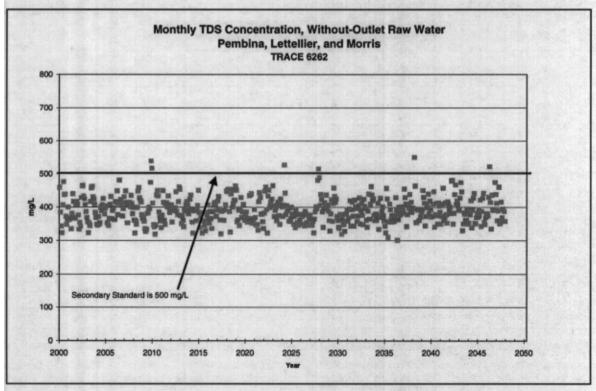


Notes: Based on data obtained from the water treatment facilities, it was assumed that the raw water SO4 concentrations would not be significantly affected by treatment.

Trace data from Drayton.





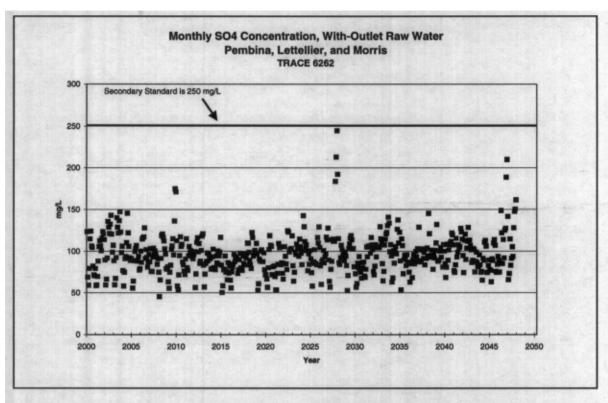


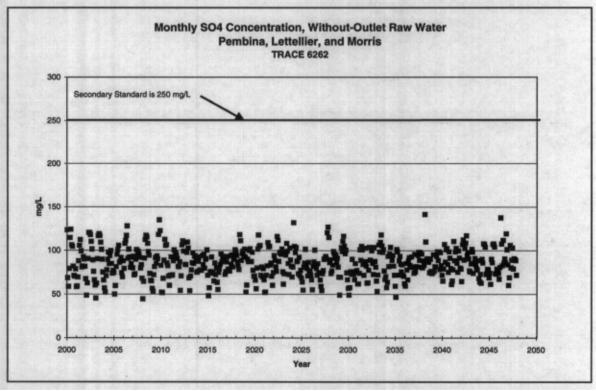
Notes: Finished water TDS concentration under without-outlet water treatment facility conditions was not modeled.

Current finished water TDS concentration at this water treatment facility was not available.

Trace data from Emerson.







Notes: Based on data obtained from the water treatment facilities, it was assumed that the raw water SO4 concentrations would not be significantly affected by treatment.

Trace data from Emerson.

Appendix A

Water Treatment Facility Information Summaries

Data Summary Sheet Devils Lake Downstream Surface Water Users Study Municipal Water Treatment Plants

City of	Grand Forks	Permit #	Water Source	Status
Water	Treatment Plant	04354	Red River	Perfected
		00835A	Red River	Perfected
Address:	503 South 4th Street	00835	Red River	Perfected
	Grand Forks, ND 58201			
Contact Person: Hazel Sletten Phone Number: (701) 746-2595				

City Profile Information

Population Served: 50,000 in Grand Forks and 5,000 - 8,000 at Grand Forks Air Force Base

Industries Served: Potato processing (1.5 - 2.0 mgd)

Foods/Potato (RDO Foods) (0.7 mgd) Pasta (Contaluna Foods) (0.2 mgd)

Use Rate:

<u>Year</u>	Daily Average Water Usage (MG)	Maximum Daily Water Usage (MG)
1994	6.73	10.0
1995	7.77	14.7
1996	7.94	10.9
1997	8.0	(information not available due to flood)

Plant Description

Rated Plant Capacity: 16.5 MGD (average and peak) Anticipated (2020) Average Water Usage: 25-

30MGD

Year of Installation: 1897 **Expansions or Upgrades:** 1936, 1956, 1968, 1974, 1984 and 1995

Source(s) of Raw Water: Red Lake River (55% - 61%) Intake Location(s): 298 Red River mile

Red River of the North (39% - 45%) see attached Figure 2.2

Raw Water Quantity:

Year	Million gallons
1994	2,490
1995	2,840
1996	2,910

1996 Monthly Average Raw Water Intake:

<u>Month</u>	Quantity, Million Gallons
T	220.2
January	228.3
February	216.8
March	250.3
April	234.7
May	238.4
June	270.7
July	244.5
August	285.8
September	261.6
October	240.4
November	226.0
December	208.8

Raw Water Quality:

Parameter	Units	Raw	Effluent
TSS (turbidity)	NTU	85	0.11
рН		8.2	9.2
"p" Alkalinity	mg/l	25	15
"M" Alkalinity	mg/l	215	86
Hardness	mg/l	264	146
TDS	mg/l	304	256
Calcium	mg/l	148	39.3
Magnesium	mg/l	117	11.3
Sodium	mg/l	N/A	33
Sulfate	mg/l	N/A	78.7
Chloride	mg/l	N/A	17.79
TOC	mg/l	10.062	N/A

see attached City of Grand Forks Raw Water Quality Profile (1994-1996)

Treatment Objectives: see attached Grand Forks Water Treatment Plant Mission Statement

Type of Treatment:

Pretreatment Clarification Lime-Soda Ash Softening

Stabilization Disinfection Fluoridation Filtration

High Service Pumping Sludge Dewatering

A complete description of these treatment processes and purposes is provided on the attached table.

Major Chemicals used and approximate quantities in each treatment process:

Chemical	Use	Quantity (Annual)	Cost /lb
Liquid Alum	Clarification	664 tons	\$0.04
Carbon dioxide	Adjust pH	610 tons	\$0.065
Powdered activated carbon	Taste and odor removal	5 tons	\$1.46
Potassium permanganate	Taste and odor removal	0	\$1.32
Cationic polymer	Coagulant Aid	8 tons	\$0.75
Pebble Quicklime	Hardness removal	2377 tons	\$0.03
Soda Ash	Hardness removal	149 tons	\$0.0925
Sodium aluminate	Coagulant	51 tons	\$0.2793
Polyphosphate	Corrosion control	25 tons	\$0.665
Chlorine gas	Disinfection	106 tons	\$0.26
Ammonia solution	Disinfection	45 tons	\$0.1068
Sodium silicofluoride	Fluoride addition	25 tons	\$0.12

Amount of Solids Generated (lb/day): 180,000 lb/day

Solids Disposal Method: Vacuum filters, landfill disposal

Approximate Cost to dispose of solids: \$5000/yr for gas and \$60,000 every five years for new trucks.

Economics of Operations:

Average Chemical Cost / MG = \$190

Based on:

1997 total chemical cost = \$510,519.92 Total gallons = 2,746,729,276

Average chem cost / 1000 gallons = \$0.19Total chem cost / 1000 gallons = \$2.19

Performance (SDWA objectives relevant to year 2000 proposed standards):

The plant will need to change to ozone or membrane treatment (for ultra or microfiltration only) to meet additional microbial log removal. Total organic carbon levels and disinfection by-products will need to be addressed. The City of Grand Forks is plans on conducting a plant scale pilot work in 1998 - 1999.

(See attached Grand Forks Tap Water Analysis summary table for drinking water quality data).

Contingency Plans (drought, flood, pollution, power failure, etc.):

Available on-site.

Additional Comments:

Devils Lake could impact Grand Forks solids dewatering system. It is undersized and is running 6 or 7 days a week. They have no proposed sulfate removal processes.

Data Summary Sheet Devils Lake Downstream Surface Water Users Study Municipal Water Treatment Plants

Grafton Water Treatment Plant Facility Permit #: 00893

Address: Box 578 Water Source: Red River

Grafton, North Dakota 58237 Status: Active

Contact Person: Arlis Bischoff **Phone Number:** (701) 352-2101

City Profile Information

Population Served: 5,000

Industries Served: Ethanol Plant- corn milling (Ag-Chem)

State Development Center (Domestic water consumption)

Use Rate:

<u>Daily Average Water Usage</u> <u>Maximum Daily Water Usage</u>

0.7 MG 1.3 MG

Plant Description

Rated Plant Capacity: Peak 3.0 MGD Anticipated (2020) Average Water Usage: 1.2 MGD

Average 3.0 MGD

Year of Installation: 1954 Expansions or Upgrades: 1979

Source(s) of Raw Water: Red River (90%)

Intake Location(s): 236 Red River mile

Park River (10%) see attached Figure 3.1

Raw Water Quantity:

<u>Year</u> <u>million gallons</u> 1996 *304 1997 235

*data obtained from NDSWC

1996 Monthly Average Raw Water Intake:

Month	Quantity, Million Gallons
January	21.98
February	21.86
March	21.55
April	15.97
May	00.00
June	8.23
July	28.88
August	30.57
September	28.68
October	25.34
November	22.20
December	21.01

Water Quality:

Parameter	Units	Raw	Effluent
TSS (turbidity)	NTU	60	N/A
рН		8.1	9.1
Alkalinity	mg/l	214	134
Hardness	mg/l	296	127
TDS	mg/l	489	306
Calcium	mg/l	172	83.6
Magnesium	mg/l	128	43.4
Sodium	mg/l	30	58
Sulfate	mg/l	81	100
Chloride	mg/l	2.3	28
TOC	mg/l	5.86	N/A

see attached Red River Water Quality (1993-1995)

Treatment Objectives: To obtain a hardness of 120 ppm

Type of Treatment:

Pretreatment Lime Softening pH Adjustment Basin Filtration

Disinfection

Major Chemicals used and approximate quantities in each treatment process:

Chemical	Use	Quantity (Annual)	Cost/lb
Lime	Softening	337,604 lbs	\$0.03
Soda Ash	Softening	88,600 lbs	\$0.11
Carbon dioxide	pH Adjustment	91,300 lbs	\$0.115
Aluminum Sulfate	Coagulation	8,820 lbs	\$0.17
Carbon	Color and Odor	7,450 lbs	\$0.62
Cationic polymer	Coagulation	1,276 lbs	\$0.65
Anionic polymer	Coagulation	324 lbs	\$0.85
Sodium Aluminate	Flocculation	12,524 lbs	\$0.29
Chlorine gas	Disinfection	11,455 lbs	\$0.42
Fluoride	Prevention	3,472 lbs	\$0.39
Polyphosphate	Stability	3,607 lbs	\$0.9

Chemical Metering Equipment Maximum Feed Rates:

Chemicals	Feed Rate Per Day
Pebble Lime Slaker and Feeder	24,000 lb
Soda Ash	4,000 lb
Aluminum Sulfate	2,000 lb
Sodium Aluminate Pump	38 gal
Carbon	750 lb
Chlorine	400 lb
Carbon Dioxide	1,800 lb
Fluoride	1,000 lb
Phosphate	500 lb
Cationic Polymer Pump	44 gal
Anionic Polymer Pump	132 gal

Amount of Solids Generated (lb/day): N/A

Solids Disposal Method: Discharge to pond

Approximate Cost to dispose of solids: \$90,000 every eight years

Economics of Operations:

Average Operation Cost (MG/year) = \$938.68

Performance (SDWA objectives relevant to year 2000 proposed standards):

New turbidimeters, filter media, computers with report review software, pH Meters, chemical injection modifications, SCADA system, improvements to existing basins and misc. electrical and minor repairs.

Long term projections for ozone disinfection and ultra and micro filtration process.

Contingency Plans (drought, flood, pollution, power failure, etc.):

The plant can withdrawal water from either the Park River or Red River.

Additional Comments:

At present no current treatment practice will remove salts.

Data Summary Sheets Devils Lake Downstream Surface Water Users Study Municipal Water Treatment Plants

City of Pembina Facility Permit #: 4054

Water Source: Red River

Address: Box 23 Status: Active

Pembina ND 58271

Contact Person: George Motl Phone Number: (701) 825-6932

City Profile Information

Population Served: 650

Industries Served: Motor Coach Industries (domestic use and washing buses)

Use Rate:

<u>Daily Average Water Usage</u> <u>Maximum Daily Water Usage</u>

0.17 MG (As reported by City) 0.576 MG

Based on 1996 and 1997 records form North Dakota State Water Commission, Pembina used less than 27,000,000 each year or an average of only 0.07 MGD.

Plant Description

Rated Plant Capacity: 0.576 MGD (average and peak) Anticipated (2020) Average Water Usage: 0.179 MGD

Year of Installation: 1970 Expansions or Upgrades: none

Source(s) of Raw Water: Red River Intake Location(s): 158.1 Red River mile

Raw Water Quantity:

Year million gallons 27

1996 Monthly Average Raw Water Intake:

Month	Quantity, Million Gallons
January	1.87
February	1.76
March	2.32
April	1.90
May	1.89
June	3.00
July	2.22
August	2.92
September	2.90
October	1.95
November	1.95
December	2.37

Water Quality:

Parameter	Units	Raw	Effluent
TSS (turbidity)	NTU	30-150	0.015
рН		8.0	9.0 - 9.2
Alkalinity	mg/l	N/A	N/A
Hardness	mg/l	375 (peak)	120
TDS	mg/l	N/A	N/A
Calcium	mg/l	N/A	92
Magnesium	mg/l	N/A	28
Sodium	mg/l	N/A	N/A
Sulfate	mg/l	N/A	N/A
Chloride	mg/l	N/A	2.5
TOC	mg/l	N/A	N/A

Treatment Objectives:

Low Turbidity, good chlorine and pH control

Type of Treatment:

Pretreatment Clarification Lime-Soda Ash Softening Corrosion Control Recarbonation

Disinfection Filtration

Attached is a process flow schematic

Major Chemicals and approximate quantities used in each treatment process:

Chemical	Use	Quantity (Annual)	Cost
Lime	Hardness removal	80,000 lbs	N/A
Alum	Pretreatment	8,500 lbs	N/A
Chlorine	Disinfection	1,950 lbs	N/A
Soda Ash	Hardness removal	7,000 lbs	N/A
Sodium Phosphate	Softening	450 lbs	N/A
Hydrochloric acid`	N/A	1,862 gallons	N/A
Carbon dioxide	Recarbonation	13,500 lbs	N/A

Amount of Solids Generated (lb/day): N/A

Solids Disposal Method: Discharge to pond

Approximate Cost to dispose of solids: N/A

Economics of Operations:

Average Operations Cost = 135, 000/year

Performance (SDWA objectives relevant to year 2000 proposed standards): The Pembina Water treatment plant operator says no changes will be necessary.

Contingency Plans (drought, flood, pollution, power failure, etc.):

Rural water, no backup power.

Additional Comments:

None

Data Summary Sheet Devils Lake Downstream Surface Water Users Study Municipal Water Treatment Plants

Drayton Water Treatment Plant Facility Permit #: 3400269

Address: 507 River Range Road Water Source: Red River

Drayton ND Status: Active

Contact Person: Ron Helm **Phone Number:** (701) 454-6370

City Profile Information

Population Served: 1000

Industries Served: Sugar Beet Plant (American Crystal Sugar)

Harvest States Elevator

Use Rate:

<u>Daily Average Water Usage</u> <u>Maximum Daily Water Usage</u>

0.25 MG 0.6 MG

Plant Description

Rated Plant Capacity: 0.72 MGD (average) Anticipated (2020) Average Water Usage: 0.33 MGD

0.76 MGD (peak)

Year of Installation: 1962 Expansions or Upgrades: 1994, 1995, 1996

Source(s) of Raw Water: Red River Intake Location(s): 206.7 Red River Mile

Raw Water Quantity:

Year million gallons 65

1996 Monthly Average Raw Water Intake:

Month	Quantity, Million Gallons
January	4.98
February	6.05
March	6.17
April	7.00
May	4.90
June	4.06
July	3.90
August	3.80
September	7.14
October	8.00
November	5.22
December	3.98

Water Quality:

Constituents	Units	Raw Water	Effluent
TSS (turbidity)	NTU	Max. 500	0.036
pН		8.0	9.0
Alkalinity	mg/l	250	90
Hardness	mg/l	320	130
TDS	mg/l	N/A	521
Calcium	mg/l	*56	N/A
Magnesium	mg/l	*26	N/A
Sodium	mg/l	*28	N/A
Sulfate	mg/l	*61	125
Chloride	mg/l	*30	154
TOC	mg/l	N/A	N/A

see attached North Dakota State Department of Health and Consolidated Laboratories Data *data obtained from United States Geological Survey

Treatment Objectives:

To obtain an effluent turbidity of 0.02 NTU, hardness removal of 130 mg/l, and kill all bacteria.

Type of Treatment:

Pretreatment Corrosion Control Disinfection Lime-Soda Ash Softening Recarbonation

Filtration

Attached is the Drayton WTP process flow schematic

All Major Chemicals and approximate quantities used in each treatment process:

Chemical	Use	Quantity	Cost/lb
Hydrite Lime	Softening	1,157 lb/day	\$0.05
Soda Ash	Softening	150 lb/day	\$0.2
Chlorine	Disinfectant	25 lb/day	N/A
Ammonia	Disinfectant	6 lb/day	N/A
Epichloro Hydren	Flocculant	0.25 ppm	N/A
Polyacrylamide	Flocculant	0.25 ppm	N/A
Alum (liquid)	Flocculant	20 mg/l	N/A
Polyphosphate	Stability	1.2 mg/l	N/A
Fluoride	Prevention	1.25 mg/l	N/A
Carbon Dioxide	pH control	100 lb/day	N/A

Chemical Metering Equipment Maximum Feed Rates:

Chemical	*Feed Rate
Hydrate Lime	1,000 mg/l
Soda Ash	300 mg/l
Chlorine	250 lb/day
Carbon Dioxide	500 lb/day
Alum	120 mg/l

^{*}Maximum feed rates at Average Flow of 500 gpm

Amount of Solids Generated (lb/day): 1,534

Solids Disposal Method: Gravity thickened and hauled to disposal lagoon

Approximate Cost of solids disposal: \$90,000 to clean out lagoon (3 acres at 12 ft. depth)

Economics of Operations:

Average Operation Cost = \$270,000/Year

Performance (SDWA objectives relevant to year 2000 proposed standards):

The Drayton Operator said they are concerned about turbidity, solids, and disinfection.

Contingency Plans (drought, flood, pollution, power failure, etc.):

To use the reservoir (dam)

Additional Comments:

Drayton is worried about treatment cost rising because the amount of solids will increase. They are also worried that the increase in quantity of water in the Red River will put more pressure on the existing dam.

Data Summary Sheet Devils Lake Downstream Surface Water Users Study Municipal Water Treatment Plants

Valley City Public Works Facility Permit #: 01096

Water Treatment Plant

Address: Box 2401 Water Source: Sheyenne River

Valley City ND 58072 Status: Active

Contact Person: Donald J. Olafson **Phone Number:** (701) 845-0652

City Profile Information

Population Served: 7,400

Industries Served: Ag-Air (produces air seeders)

Drog Plastics (manufactures plastic bottles) Case IH (manufactures computer chips)

Other Users: State Fish Hatchery

Two Golf Courses

Use Rate:

Daily Average Water Usage Maximum Daily Water Usage

1.0 MG 2.2 MG

Plant Description

Rated Plant Capacity: 4.0 MGD (peak and average) Anticipated (2020) Average Water Usage: 1.0 MGD

Year of Installation: 1972 Expansions or Upgrades: 1993

Source(s) of Raw Water: Sheyenne River Intake Location(s): 253 Sheyenne River Mile

2 wells located adjacent to river

The primary source of raw water is the Sheyenne river. However, during the summer months elevated algae levels in the river cause the city to use the two wells. The water quality is assumed to be equivalent between the two sources.

Raw Water Quantity:

Year Million Gallons

1996 294

1996 Monthly Average Sheyenne River Raw Water Intake:

Quantity, Million Gallons
21.88
24.08
22.14
21.50
26.57
27.05
28.55
33.69
24.21
22.68
21.08
21.11

Water Quality:

Parameter	Units	Raw	Effluent
TSS (turbidity)	NTU	20	0.05
рН		7.5	8.96
Alkalinity	mg/l	259	13
Hardness	mg/l	290	139
Total Dissolved Solids	mg/l	545	374
Calcium	mg/l	57.9	N/A
Magnesium	mg/l	35.4	13.5
Sodium	mg/l	63.5	71.6
Sulfate	mg/l	206	150
Chloride	mg/l	14.3	29.2
TOC	mg/l	N/A	N/A

Treatment Objectives: For the plant to always meet the Safe Drinking Water Act standards.

Type of Treatment:

Pretreatment Coagulation
Flocculation Sedimentation
Precipitation Disinfection
Filtration

Attached is the Valley City WTP process flow schematic.

Major Chemicals and approximate quantities used in each treatment process:

Chemical	Use	Quantity (annual)	Cost
Carbon	Taste and odor control	1,200 lb	N/A
Lime	Softening	600 ton	N/A
Sodium Aluminate	Softening	8400 lb	N/A
Polymer	Softening	600 lb	N/A
Phosphate	Corrosion Control	8400 lb	N/A
Liquid CO2	pH Control	108,000 lb	N/A
Chlorine	Disinfection	15,600 lb	N/A

Amount of Solids Generated (lb/day): 5,000

Solids Disposal Method: Hauled out to inert landfill and dried

Approximate Cost for solids disposal: \$5000/year

Economics of Operations:

Average Operation Cost = \$1million/MG

Performance (SDWA objectives relevant to year 2000 proposed standards):

The SDWA may not be applicable because the Valley City WTP treats for a population of 10,000 people.

Contingency Plans (drought, flood, pollution, power failure, etc.):

Plans are to rely on wells. Wells are used during the summer months when algae level in Sheyenne are high. Wells are 48 feet away from the water and can deliver 2 MGD.

Additional Comments:

Data Summary Sheet Devils Lake Downstream Surface Water Users Study Municipal Water Treatment Plants

Fargo Wa	ater Treatment Plant	Permit #	Water Source	Status
		*00794	Red River	Cond. Approved
Address:	435 14th Ave S	01091	Sheyenne River	Perfected
	Fargo ND 58103	04718	Sheyenne River	Held in Abeyance
Contact Person	: Robert Welton		Phone Number:	(701) 241-1552
	Ron Hendricksen			(701) 241-1470

^{*}The Red River intake, which is Fargo's primary source of water, is located upstream from the Sheyenne River Intake. A change in the composition of the Sheyenne River will not affect the Fargo Water Treatment Plant Red River intake.

City Profile Information

Population Served: 80,000 to 85,000

Industries Served: North Dakota State University

Pepsi

American Linen (washing)

Use Rate:

<u>Daily Average Water Usage</u>
11.5 MG

Maximum Daily Water Usage
23.0 MG

Refer to Chart 1 "City of Fargo Per Capita Water Usage" and refer to Chart 3 "City of Fargo Annual Water Usage"

Plant Description

Rated Plant Capacity: 14 MGD (average) Future (2020) Plant Capacity: 14 MGD (average)

30 MGD (peak) 30 MGD (peak)

Year of Installation: 1997 Expansions or Upgrades: none

Source(s) of Raw Water: Red River (primary) **Intake Location(s):** 451.7 Red River mile

Sheyenne River (secondary) 29.5 Sheyenne River mile

Raw Water Quantity:

Year Million gallons 1996 4,747

Water Quality:

Constituent	Units	Raw Water	Effluent
TSS (Turbidity)	NTU	2-500 NTU	0.05-0.25
pH		7.6-8.4	8.5-9.3
Alkalinity	mg/l	240	80-120
Hardness	mg/l	N/A	80-140
Total Dissolved Solids	mg/l	350	N/A
Sulfate	mg/l	120-170	N/A
Chloride	mg/l	N/A	N/A
TOC	mg/l	N/A	N/A

Treatment Objectives: For the plant to obtain a hardness of 120 mg/l.

Type of Treatment:

Presedimentation Softening
Ozone disinfection Filtration
Sludge Drying

Attached is the Fargo WTP process flow schematic

Major Chemicals used and quantities of those chemicals for each treatment process:

Chemical	Use	Quantity (avg dosage)	Cost (\$/gal of water treated)
Aluminum Sulfate	Flocculent	40 ppm	\$0-\$150
Polymers	Flocculent	1 ppm	\$0-\$15
Carbon	Taste and odor control	5 ppm	\$0-\$40
Lime	hardness reduction	200 ppm	\$180-\$250
Soda Ash	hardness reduction	60 ppm	\$10-\$160
Sodium Aluminate	hardness reduction	10 ppm	\$5-\$15
Polymer	coagulant	2 ppm	\$0-\$3
Carbon dioxide	recabonation	15 ppm	\$30-\$70

Amount of Solids Generated (lb/day): 68.6 tons/day (30 percent solids), 21.0 tons/day dry

Solids Disposal Method: Filter presses drying sludge to 30 percent solids. Hauled to landfill for daily cover.

Approximate Cost: There is an indirect cost of \$25/ton of sludge that is hauled to the landfill.

Economics of Operations:

1997 Average Operational Cost/million gallons = \$834.00

The 1998 Annual Chemical Bidding Summary is provided on the attached table.

Performance (SDWA objectives relevant to year 2000 proposed standards):

No Anticipated Changes.

Contingency Plans (drought, flood, pollution, power failure, etc.):

Drought: The Fargo WTP has water rights to Lake Ashtabula and Sheyenne River.

Flood: The WTP is built above 100 year flood elevation.

Pollution: Sheyenne water is our alternate source.

Power Failure: There are two electrical feeds from NSP.

Additional Comments:

The Fargo treatment facility is not designed to handle or remove dissolved solids. An increase level of TDS in the Sheyenne River due to discharge from Devils Lake would change the water quality and would effect Fargo only when using Sheyenne raw water.

Data Summary Sheets Devils Lake Downstream Surface Water Users Study Municipal Water Treatment Plants

City of Morris Permit # N/A Water Source: Red River

Address: Box 670

Morris Manitoba Canada

Contact Person: Richard Dupree **Phone Number:** (204) 746-2790

City Profile Information

Population Served: 1,700

Industries Served: Hog farmers

Use Rate:

<u>Daily Average Water Usage</u> <u>Peak Average Water Usage</u>

0.73 MG N/A

Plant Description

Rated Plant Capacity: 0.73 MGD (average) Anticipated (2020) Average Water Usage: N/A

0.82 MGD(peak)

Year of Installation: 1998 Expansions or Upgrades: none

Source(s) of Raw Water: Red River Intake Location(s): 64.5 Red River mile

Raw Water Quantity:

Year Million Gallons 1996 266 MG

Water Quality:

Parameter	Units	Raw	Effluent
TSS (turbidity)	NTU	N/A	N/A
pН		7.9	8.8
Non-Carbonate	mg/l	102	104
Hardness	mg/l	224	166
TDS	mg/l	N/A	N/A
Calcium	mg/l	N/A	N/A
Magnesium	mg/l	N/A	N/A
Sodium	mg/l	N/A	N/A
Sulfate	mg/l	N/A	N/A
Chloride	mg/l	N/A	N/A
TOC	mg/l	N/A	N/A

Treatment Objectives: N/A

Type of Treatment: Clarification Sand filter

Recarbonation Lime-soda ash softening

Major Chemicals and approximate quantities used in each process:

Chemical	Use	Quantity	Cost		
Lime	Hardness removal	N/A	N/A		
Soda Ash	Hardness removal	N/A	N/A		
Alum	Coagulant	N/A	N/A		
Powder Carbon	N/A	N/A	N/A		
Chlorine	Disinfectant	N/A	N/A		
Fluoride	Prevention	N/A	N/A		
Polymer 4418	Flocculant	N/A	N/A		

Amount of Solids Generated (lb/day): N/A

Solids Disposal Method: Settling ponds/lime dewater and return.

Approximate Cost to depose of solids: N/A

Economics of Operations: N/A

Performance (SDWA objectives relevant to year 2000 proposed standards): N/A

Contingency Plans (drought, flood, pollution, power failure, etc.): N/A

Appendix B

Mitigation Model User's Manual

The mitigation model was developed by Barr Engineering Company as part of the Devils Lake, North Dakota, Downstream Surface Water Users Study. The model can be obtained from the U.S. Army Corps of Engineers, St. Paul District. The model is in Microsoft Excel 97 format. Both the Phase I and the Phase II mitigation models are located in the same spreadsheet, "Model1_Template.xls".

File Management

The mitigation models, Phase I and II, are comprised of both spreadsheet equations and macros. In order to make the model flexible to changes in parameter assumptions as well as trace data, the macros "look" for files containing a certain name and trace number. Trace numbers may vary, there is no limit to what number you use, but the rest of the file name MUST conform to a certain convention in order for the macros to function properly.

ASCII files from HEC-5/Q output MUST be named with the same convention as those provided to Barr Engineering for this study. That is, the files must be as follows: a three-letter station name, then the trace number, then a multiple letter extension which designates the trace (with-outlet or without-outlet). The extensions for each of the stations used in this study are as follows:

- ! Valley City (val)
- ! Kindred (kin)
- ! Halstad (hal)
- ! Grafton (osl)
- ! Drayton (dry)
- ! Emerson (emr)

Therefore, the ASCII file for the station at Valley City, with- and without-outlet should be called val(trace number).(letter extension with-outlet) and val(trace number).(letter extension without-outlet), respectively. The user will specify the trace number, file path, and extension designations.

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In addition, these files must be placed in a certain set of folders. All files should be organized on the user's computer as follows:

Trace files can be located on any specified hard drive in a folder (subdirectory) called "Traces." The path designation is specified in the "Macros2.xls" file. Each of the trace data files must also be organized into a subfolder that denotes the corresponding trace number. For example, trace 6262 files on the C drive must all be in C:\traces\trace6262\. If the user's files are not organized in this manner, the macros will not operate correctly.

The mitigation model should be put in a separate folder (for example, $C:\mbox{model}\Model1_Template.xls$).

Executing the Phase I and Phase II Models

The model consists of an Excel spreadsheet, "Model1_Template.xls," that takes user inputs for several parameters and calculates mitigation costs (see Valley City example at the end of this appendix). The spreadsheet contains many linked equations and a macro that reads the pertinent with- and without-outlet concentrations for the desired trace. This spreadsheet model can run only one trace at a time. Therefore, it is advised that this spreadsheet be used as a template to run a given trace and then save it to a different, descriptive file name. In this manner, the user is less likely to confuse data with the wrong trace number or overwrite output. The model output, for both the Phase I and Phase II models, is a table that summarizes the present worth cost increase due to pumping for each of the eight treatment facilities analyzed in this study. These costs are presented as present worth (1998 dollars) and as annualized present worth (1998 dollars) over 50 years.

This model can be used to analyze traces other than the seven that were used in this study. However, the equations developed for the model are only valid at concentrations equal or less than those in the worst of the seven traces that Barr Engineering Company analyzed. If new traces reflecting greater river impacts are used, the model cannot be expected to accurately estimate cost increases to the water treatment facilities. Also, the global model was created to handle changes in treatment plant assumptions (the model input parameters). For each plant, the assumptions are listed in the first few columns of the worksheet entitled the city's name (see Valley City Input Data example printout). These parameters may be changed by the user, and computations will change accordingly. **However**, any changes must be made prior to running the macros, as the macros use some of these parameters when performing their functions.

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Before the macros can be run for any new trace (traces not analyzed in this study), the ASCII text files from the HEC-5/Q model must be imported into Excel. This can be accomplished with a macro entitled "Import." This macro is located in the file entitled "macros2.xls." Simply enter the trace number, path designation, and letter extension that is to be imported into Excel format and press the button entitled "PRESS HERE to Execute 'Import' Macro."

The macro used in the Phase I and Phase II models is entitled "calculations." This macro is located in the file entitled "Model1_Template.xls." The "calculations" macro contains several other macros which perform a variety of functions. To run the "calculations" macro, simply enter the trace number to be analyzed and the path to the subdirectory where the input files are located and click on the button bearing the macro's name on the worksheet (tab) entitled "TRACE NUMBER." If the user wishes to learn how the macros operate in greater detail, they are documented in the Visual Basic sheet in Excel.

Input Data, Sludge Handling Calculations, and Softening Calculations are all located on the worksheet titled as the respective city's name. Ion Exchange Calculations, Well Calculations, and Rural Water Calculations are located on the worksheets with the city's name followed by either Ion Exchange, Wells, or Rural Water respectively. Summary worksheets for Phase I and Phase II are also located in the model template and will automatically be updated for any trace that is analyzed. The summary worksheets for Phase I and Phase II are respectively named "SUMMARY-PHASE I" and "SUMMARY-PHASE II."

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VALLEY CITY INPU	T DATA		
			
NOTE TO USER:			
You must specify the trace			
proceeding. The trace nulabeled "TRACE NUMBE			
calculations". If you fail			
will not be accurate.	to tollow these step	is, your results	
After you have specified t	he trace number a	nd have run the macro.	
t is advised that you save			
Monthly Flavo Takan fr	om the Chavenne	Diver	
Monthly Flows Taken fr	om me sneyenne	Ulvei	
Month	Flow		
	(gal/month)		
Jan	21,880,000		
Feb	24,080,000		
Mar	22,140,000		
Apr	21,510,000		
May Jun	26,570,000 27,050,000		
July	28,550,000	+	
Aug	33,690,000		
Sept	24,210,000		
Oct	22,680,000		
Nov	21,080,000		
Dec	21,110,000		
Chemical Dosages (lb o	Dose (lb/lb)		
Lime	2.64		
Sodium Aluminate	0.018		•
CO ₂	0.238	 	
Polymer	0.013		
nemical Costs (\$ per l	b of Chemical)		
Chemical	Unit Cost		÷
Lime	\$0.03		
Sodium Aluminate	\$0.27		
CO ₂	\$0.06		
Polymer	\$2.92		
Annual Interest Rate			:
0.07125			•
Softening Objective		· 	
139	mg/L		
Cludgo Broduction Pate			
Sludge Production Rate (lb sludge (15% solids) / I			
is sidage (to /e solids) / I	- 10ta Hardinoss)	+	
3.15			

			State/	
Reach	Permittee	Use	Province	Permit Number
Between L	ake Winnipeg and Emerson	1		1
	Fox, C. J.	Irrigation	Manitoba	N/A
	Searle Greenhouses Ltd.	Irrigation	Manitoba	N/A
	Searle Greenhouses Ltd. Nisbet, Donald A.	Irrigation	Manitoba	N/A N/A
	Southwood Golf and Country Club	Irrigation Irrigation	Manitoba Manitoba	N/A N/A
	Norquay, I. P.	Irrigation	Manitoba	N/A
	Cybulsky, K. A.	Irrigation	Manitoba	N/A
	Shale, H. J.	Irrigation	Manitoba	N/A
	Shale, H. J.	Irrigation	Manitoba	N/A
	Praznik, B. J. & M. H. Praznik, B.	Irrigation Irrigation	Manitoba Manitoba	N/A N/A
	Praznik, Thomas & Rose	Irrigation	Manitoba	N/A
	Yablonski, J. T. & G. Y.	Irrigation	Manitoba	N/A
	Topor, Charlie	Irrigation	Manitoba	N/A
	Kaminski, W.	Irrigation	Manitoba	N/A
	Devos, D. & M.	Irrigation	Manitoba	N/A N/A
	Sokolowski, Victor Scott, Gordon	Irrigation Irrigation	Manitoba Manitoba	N/A N/A
	Glen Eden Memorial Gardens	Irrigation	Manitoba	N/A
	Addis, T. S.	Irrigation	Manitoba	N/A
	Middlechurch Home, etc.	Irrigation	Manitoba	N/A
	Schwabe, J. A. G. & D. E.	Irrigation	Manitoba	N/A
	Pritchard, H. T. & M.	Irrigation	Manitoba	N/A
	Gayner, J. R. & B. T. Loganberg, R. B. & A. J.	Irrigation Irrigation	Manitoba Manitoba	N/A N/A
	Loganberg, R. B. & A. J.	Irrigation	Manitoba	N/A
	Winnipeg, The City of	Irrigation	Manitoba	N/A
	The Metropolitan Corporation of Greater Winnipeg (Crescent Drive Golf Course)	Irrigation	Manitoba	N/A
	St. Boniface General Hospital	Irrigation	Manitoba	N/A
	Reimer, D. S. The Metropolitan Corporation of Greater Winnipeg (Kildonan Golf Course)	Irrigation	Manitoba Manitoba	N/A N/A
	Winnipeg, The City of	Irrigation Irrigation	Manitoba	N/A N/A
	Manitoba Rugby Union	Irrigation	Manitoba	N/A
	Connery, James & Dorothy	Irrigation	Manitoba	N/A
	Gibson, James & Connery, Edward J.	Irrigation	Manitoba	N/A
	Daman, J., C. & W.	Irrigation	Manitoba Manitoba	N/A N/A
	Phippen, J. W. Woytowicz, P.	Irrigation Irrigation	Manitoba	N/A N/A
	Woytowicz, P.	Irrigation	Manitoba	N/A
	Mudry, N. & A.	Irrigation	Manitoba	N/A
	Mudry, N. & A.	Irrigation	Manitoba	N/A
	Cenerini, R. & C.	Irrigation	Manitoba	N/A
	Campeau, Eva Richardson Stock Farms Ltd.	Irrigation	Manitoba Manitoba	N/A N/A
	Meyer, J.	Irrigation Irrigation	Manitoba	N/A N/A
	Bullet Development Ltd.	Irrigation	Manitoba	N/A
	Cenerini, R.	Irrigation	Manitoba	N/A
	Wiens, Theodor & Daniel	Irrigation	Manitoba	N/A
	McDonald, M. & C.	Irrigation	Manitoba	N/A N/A
	James Alty and Joan Alty Parisien, Paul	Irrigation Irrigation	Manitoba Manitoba	N/A N/A
	Canada - Agriculture (Glenlea Research Station)	Irrigation	Manitoba	N/A
	Canada - Agriculture (Glenlea Research Station)	Irrigation	Manitoba	N/A
	Canada - Agriculture (Glenlea Research Station)	Irrigation	Manitoba	N/A
	University of Manitoba (Glenlea Research Station)	Irrigation	Manitoba	N/A
	Alty, J. S. R.	Irrigation	Manitoba Manitoba	N/A N/A
	McLeod, Jerry Roy & Bonnie Barbara Petrie, Brian William	Irrigation Irrigation	Manitoba	N/A N/A
	Shupena, E. S. & R. S.	Irrigation	Manitoba	N/A
	Blatta, J., L. & C.	Irrigation	Manitoba	N/A
	Barnabe, G.	Irrigation	Manitoba	N/A
	Kostal, John & Carolyn	Irrigation	Manitoba	N/A
	Eidse, G. L. & H. E. Riverview Golf & Country Club	Irrigation	Manitoba Manitoba	N/A N/A
	Lafond, N. O.	Irrigation Irrigation	Manitoba	N/A N/A
	Fontaine, J. R. G.	Irrigation	Manitoba	N/A
	Fontaine Farms Ltd.	Irrigation	Manitoba	N/A

Notes: The database information obtained from North Dakota included many permittee names that were truncated (maximum of 15 characters). Permit information was obtained from the State/Province list of permitted river water users.

			State/	
Reach	Permittee	Use	Province	Permit Number
Reacii	Leclair Freres Ltee.	Irrigation	Manitoba	N/A
	Heinrichs, Dwight Peter & Eugene Charles	Irrigation	Manitoba	N/A
	Houle Farms Ltd.	Irrigation	Manitoba	N/A
	Valley's Edge Produce	Irrigation	Manitoba	N/A
	Nisbet, Donald A.	Irrigation	Manitoba	N/A
	Southwood Golf and Country Club	Irrigation	Manitoba	N/A
	Winnipeg, The City of	Other	Manitoba	N/A
	Sorin, Jean	Domestic	Manitoba	N/A
	Ducks Unlimited	Waterfowl Conservation	Manitoba	N/A
Between E	Emerson and Drayton			
	Raney, Robert	Irrigation	North Dakota	1342
	Emanuelson, Ran	Irrigation	North Dakota	1342A
	Raney, David R.	Irrigation	North Dakota	1342B
	Raney, Philip C	Irrigation	North Dakota	1342C
	Raney, David R. Raney, Philip C	Irrigation	North Dakota North Dakota	1342D 1342E
	Raney, David R.	Irrigation	North Dakota	1342E
	Raney Trust, Ro	Irrigation Irrigation	North Dakota	1342F 1342G
	Black, Susan	Irrigation	North Dakota	1342H
	Emanuelson, Ran	Irrigation	North Dakota	1342J
	Thompson, G & B	Irrigation	North Dakota	4403
	Friese, Ronald	Irrigation	North Dakota	1244
	Thompson, G & B	Irrigation	North Dakota	4403
	Friese, Ronald	Irrigation	North Dakota	1244
	Thompson, G & B	Irrigation	North Dakota	4403
Between [Drayton and Oslo			
	Altendorf, Mart	Irrigation	North Dakota	4190
	Schumacher, Joh	Irrigation	North Dakota	4325
	Schumacher, Joh	Irrigation	North Dakota	4325
	Grzadzielewski,	Irrigation	North Dakota	4282
	Grzadzielewski,	Irrigation	North Dakota	4335
Between C	Oslo and Grand Forks			T
	Gowan, Charles	Irrigation	North Dakota	4736
	Gowan, Charles	Irrigation	North Dakota	4689
	Gowan, Charles	Irrigation	North Dakota	4689
	Gowan, Charles Gowan, Charles	Irrigation	North Dakota	4435 1046
	Gowan, Charles	Irrigation Irrigation	North Dakota North Dakota	1046
	Campbell, Thomas	Irrigation	North Dakota	4740
	Longtin, Terry	Irrigation	North Dakota	617C
	U.S. Fish and W	Irrigation	North Dakota	4354
	Mallinger Brothers	Major Crop Irrigation	Minnesota	540072
	Campbell, Adelaide	Major Crop Irrigation	Minnesota	921218
	Mallinger Brothers	Major Crop Irrigation	Minnesota	931177
	Ryan Children Trusts	Major Crop Irrigation	Minnesota	811094
	Ryan Children Trusts	Major Crop Irrigation	Minnesota	811094
	I		Minnesota	881268
· ·	Driscoll Brothers	Major Crop Irrigation		
ļ	Peterson, Douglas	Major Crop Irrigation	Minnesota	951080
	Peterson, Douglas Valley Golf Association			
	Peterson, Douglas Valley Golf Association Grand Forks and Halstad	Major Crop Irrigation Golf Course	Minnesota Minnesota	951080 901134
	Peterson, Douglas Valley Golf Association Grand Forks and Halstad Brown, Larry	Major Crop Irrigation Golf Course Irrigation	Minnesota Minnesota North Dakota	951080 901134 454
	Peterson, Douglas Valley Golf Association Grand Forks and Halstad Brown, Larry Grand Forks Par	Major Crop Irrigation Golf Course Irrigation Irrigation	Minnesota Minnesota North Dakota North Dakota	951080 901134 454 1305P
	Peterson, Douglas Valley Golf Association Grand Forks and Halstad Brown, Larry Grand Forks Par Grand Forks Cou	Major Crop Irrigation Golf Course Irrigation Irrigation Irrigation	Minnesota Minnesota North Dakota North Dakota North Dakota	951080 901134 454 1305P 4582
	Peterson, Douglas Valley Golf Association Grand Forks and Halstad Brown, Larry Grand Forks Par Grand Forks Cou Grand Forks Par	Major Crop Irrigation Golf Course Irrigation Irrigation Irrigation Irrigation Irrigation	Minnesota Minnesota North Dakota North Dakota North Dakota North Dakota North Dakota	951080 901134 454 1305P 4582 4385
	Peterson, Douglas Valley Golf Association Grand Forks and Halstad Brown, Larry Grand Forks Par Grand Forks Cou Grand Forks Par All Seasons Gar	Major Crop Irrigation Golf Course Irrigation Irrigation Irrigation Irrigation Irrigation Irrigation Irrigation	Minnesota Minnesota North Dakota North Dakota North Dakota North Dakota North Dakota North Dakota	951080 901134 454 1305P 4582 4385 4899
	Peterson, Douglas Valley Golf Association Grand Forks and Halstad Brown, Larry Grand Forks Par Grand Forks Cou Grand Forks Par All Seasons Gar Grand Forks Cou	Major Crop Irrigation Golf Course Irrigation	Minnesota Minnesota North Dakota	951080 901134 454 1305P 4582 4385 4899 1081
	Peterson, Douglas Valley Golf Association Grand Forks and Halstad Brown, Larry Grand Forks Par Grand Forks Cou Grand Forks Par All Seasons Gar Grand Forks Cou Bunde Farms	Major Crop Irrigation Golf Course Irrigation	Minnesota Minnesota North Dakota	951080 901134 454 1305P 4582 4385 4899 1081 4348
	Peterson, Douglas Valley Golf Association Grand Forks and Halstad Brown, Larry Grand Forks Par Grand Forks Cou Grand Forks Par All Seasons Gar Grand Forks Cou Bunde Farms Leclerc, Ray	Major Crop Irrigation Golf Course Irrigation	Minnesota Minnesota Minnesota North Dakota	951080 901134 454 1305P 4582 4385 4899 1081 4348 4380
	Peterson, Douglas Valley Golf Association Grand Forks and Halstad Brown, Larry Grand Forks Par Grand Forks Cou Grand Forks Par All Seasons Gar Grand Forks Cou Bunde Farms Leclerc, Ray Bunde Farms	Major Crop Irrigation Golf Course Irrigation	Minnesota Minnesota Minnesota North Dakota	951080 901134 454 1305P 4582 4385 4899 1081 4348 4380 4348
	Peterson, Douglas Valley Golf Association Grand Forks and Halstad Brown, Larry Grand Forks Par Grand Forks Cou Grand Forks Par All Seasons Gar Grand Forks Cou Bunde Farms Leclerc, Ray Bunde, Ardell T	Major Crop Irrigation Golf Course Irrigation	Minnesota Minnesota Minnesota North Dakota	951080 901134 454 1305P 4582 4385 4899 1081 4348 4380 4348
	Peterson, Douglas Valley Golf Association Grand Forks and Halstad Brown, Larry Grand Forks Par Grand Forks Cou Grand Forks Par All Seasons Gar Grand Forks Cou Bunde Farms Leclerc, Ray Bunde Farms	Major Crop Irrigation Golf Course Irrigation	Minnesota Minnesota Minnesota North Dakota	951080 901134 454 1305P 4582 4385 4899 1081 4348 4380 4348

Notes: The database information obtained from North Dakota included many permittee names that were truncated (maximum of 15 characters). Permit information was obtained from the State/Province list of permitted river water users.

			State/			
Reach	Permittee	Use	Province	Permit Number		
	Loyland, Art Jr.	Irrigation	North Dakota	4887		
	Myron, Duane R.	Irrigation	North Dakota	4332		
	J.O. Thorson FA	Irrigation	North Dakota	4001		
	Thompson, Denni	Irrigation	North Dakota	4773		
	Thompson, Denni	Irrigation	North Dakota	4774		
	Galegher Farms,	Irrigation	North Dakota	4873		
	Sondreal Farms, Merrill, Allen & Aaron	Irrigation Major Crop Irrigation	North Dakota Minnesota	4226 734244		
	Adams, Darrell	Major Crop Irrigation	Minnesota	761429		
	Merrill, Allen & Aaron	Major Crop Irrigation	Minnesota	901108		
	Merrill, Allen & Aaron	Major Crop Irrigation	Minnesota	901108		
	Anderson-Tronnes Farms	Major Crop Irrigation	Minnesota	901041		
	Scott W Knutson Inc.	Major Crop Irrigation	Minnesota	941144		
	W K E Farms Inc.	Major Crop Irrigation	Minnesota	911251		
	Brekke Brothers Inc.	Major Crop Irrigation	Minnesota	901333		
	Merrill, Allen & Aaron	Major Crop Irrigation	Minnesota	901098		
	W K E Farms Inc.	Major Crop Irrigation	Minnesota	921200		
	Burd, Douglas J	Major Crop Irrigation	Minnesota	931254		
	Spokely, Rodney	Major Crop Irrigation	Minnesota	610062		
	Burd, Douglas J	Major Crop Irrigation	Minnesota	911276		
	Skalet, Keith M	Major Crop Irrigation	Minnesota	901158		
	Furuseth Brothers	Major Crop Irrigation	Minnesota	901191		
Between I	Halstad and "Junction"					
	There were no permitted users identified between Halstad an	nd "Junction"				
Between "	'Junction" and Kindred					
	Rivertree Rainm	Irrigation	North Dakota	4210		
	Johnson, Alden	Irrigation	North Dakota	4189		
	Jenner, Frances	Irrigation	North Dakota	1089		
	Kasowski, Mark	Irrigation	North Dakota	3779		
	Loberg, Leslie	Irrigation	North Dakota	515		
	Messner, Dougla Scholz, Earl W.	Irrigation Irrigation	North Dakota North Dakota	5115 2358		
Daturaan I	Kindred and Lisbon	Imgation	NOITH Dakota	2336		
Detween r		Inc	L Marth Balance	4050		
	Pfingsten, Moni	Irrigation	North Dakota North Dakota	4650 3605		
	Pfingsten, Orvi McRitchie, Robe	Irrigation Irrigation	North Dakota	4780		
	Stoffel, Peter	Irrigation	North Dakota	3606		
	Evanson, Roger	Irrigation	North Dakota	4747		
	Kaspari, David	Irrigation	North Dakota	2710		
	Evanson, Roger	Irrigation	North Dakota	2411		
	Froemke, Argil	Irrigation	North Dakota	757		
	Friese, Ronald	Irrigation	North Dakota	1241		
	Friese, Ronald	Irrigation	North Dakota	698		
	Friese, Ronald	Irrigation	North Dakota	1241		
	Friese, Ronald	Irrigation	North Dakota	3715		
	Weisenhaus, Gle	Irrigation	North Dakota	3756		
	Rotenberger, Ro	Irrigation	North Dakota	2424C		
	Qual Grain	Irrigation	North Dakota	3614		
Between L	Lisbon and Valley City					
	Krebsbach, Mark	Irrigation	North Dakota	3588		
	Roweb Irrigatio	Irrigation	North Dakota	397		
	Oak Irrigation	Irrigation	North Dakota	641		
	Lisbon Bissell	Irrigation	North Dakota	1227		
	Lambrecht, Alle	Irrigation	North Dakota	2012		
	Lambrecht, Alle	Irrigation	North Dakota	2012		
	Hoenhouse, Harv	Irrigation	North Dakota	2011		
	Hoenhouse, Harv	Irrigation	North Dakota	2011		
	Hieb, Jerry Hieb, Jerry	Irrigation Irrigation	North Dakota North Dakota	1976 1976		
		Irrigation	North Dakota	1976 1976A		
		milidation	i inoitil Dakola	13/0A		
	Hieb, Jerry					
	Wendel, Rudy	Irrigation	North Dakota	1573		

Notes: The database information obtained from North Dakota included many permittee names that were truncated (maximum of 15 characters). Permit information was obtained from the State/Province list of permitted river water users.

			State/			
Reach	Permittee	Use	Province	Permit Number		
	Barnes County W	Fish & Wildlife	North Dakota	4126		
Between	Valley City and Cooperstown					
	Town & Country	Irrigation	North Dakota	592		
	Ingstad, Robert	Irrigation	North Dakota	653A		
	Sisters of Mary	Irrigation	North Dakota	2198		
	Oak Irrigation	Irrigation	North Dakota	682		
	Sisters of Mary	Irrigation	North Dakota	2198		
	U.S. Fish and W	Recreation	North Dakota	400		
	U.S. Fish and W	Recreation	North Dakota	416		
	U.S. Fish and W	Recreation	North Dakota	1855		
	U.S. Fish and W	Fish & Wildlife	North Dakota	4595		
	U.S. Fish and W	Fish & Wildlife	North Dakota	4594		
Between	Cooperstown and the proposed outlet					
	Galde, Lloyd	Irrigation	North Dakota	607		
	Messner, Dougla	Irrigation	North Dakota	4999		
	Lundeby, Iver G	Irrigation	North Dakota	1889		
	Krebsbach, Mark	Irrigation	North Dakota	2206		
	Krebsbach, Mark	Irrigation	North Dakota	3246		

Notes: The database information obtained from North Dakota included many permittee names that were truncated (maximum of 15 characters).

Permit information was obtained from the State/Province list of permitted river water users.

Minnesota Permitted Users

				Water	Use Appropri	ation	Annual Reported Water Use (MGY)								
Permit #	Permittee	Use Code *	Source	Acres	GPM	MGY	1988	1989	1990	1991	1992	1993	1994	1995	1996
450008	AMERICAN CRYSTAL SUGAR	241	RED RIVER OF THE NORTH			1210.5		24.0	29.5		8.0			6.3	
540072	MALLINGER BROTHERS	290	RED RIVER OF THE NORTH	235	500	10.0				4.0	3.6				
580029	OSLO, CITY OF	211	RED RIVER OF THE NORTH		75	20.8	20.5	17.8	18.3	17.9	18.9	10.1			
610062	SPOKELY, RODNEY	290	RED RIVER OF THE NORTH	40	500	11.0									
630213	AMERICAN CRYSTAL SUGAR-DRAYTON	241	RED RIVER OF THE NORTH			1385.5	227.0	264.0	211.1	181.5	77.8	299.0	40.0	35.0	77.8
670191	MOORHEAD PUBLIC SERVICE	222	RED RIVER OF THE NORTH			9000.0					0.1	0.0	0.1	0.1	0.1
670191	MOORHEAD PUBLIC SERVICE	222	RED RIVER OF THE NORTH			9000.0									
720042	GULLY FARMS ENTERPRISES	296		720	4045	586.5							210.0		
734222	AMERICAN CRYSTAL SUGAR	283	RED RIVER OF THE NORTH	9	125	1.6	2.7	3.3	2.5	2.7	1.2	0.8	1.2	1.4	2.1
734244	MERRILL, ALLEN & AARON	290	RED RIVER OF THE NORTH	185	700	23.7			23.9		18.8	5.0	5.0	10.0	10.0
761429	ADAMS, DARRELL	290	RED RIVER OF THE NORTH	30		7.0									
771852	MOORHEAD PUBLIC SERVICE	211	RED RIVER OF THE NORTH		6950	3650.0	1047.6	1061.9	918.2	891.8	831.5	761.8	724.4	1176.9	1222.2
811094	RYAN CHILDREN TRUSTS	290	RED RIVER OF THE NORTH	302	800	25.0				2.3	5.2		2.1		
811094	RYAN CHILDREN TRUSTS	290	RED RIVER OF THE NORTH	302	800	25.0					9.7	19.7		7.3	
851185	MOORHEAD, CITY OF	283	RED RIVER OF THE NORTH	3	100	1.3	2.1		1.0		0.9	1.0			
881268	DRISCOLL BROTHERS	290	RED RIVER OF THE NORTH	79	1200	12.9		12.9	12.9		13.0		11.9		
891193	MOORHEAD COUNTRY CLUB	281	RED RIVER OF THE NORTH	72	300	11.7			12.6	11.0	15.0	11.7	14.1	12.5	14.7
901041	ANDERSON-TRONNES FARMS	290	RED RIVER OF THE NORTH	132	800	20.4			20.4	20.2	20.0	1.5		11.1	
901098	MERRILL, ALLEN & AARON	290	RED RIVER OF THE NORTH	182	700	22.8				7.6			6.6	16.7	13.8
901108	MERRILL, ALLEN & AARON	290	RED RIVER OF THE NORTH	220	700	22.0				6.5					
901108	MERRILL, ALLEN & AARON	290	RED RIVER OF THE NORTH	220	700	22.0									
901134	VALLEY GOLF ASSOCIATION	281	RED RIVER OF THE NORTH	74	300	12.3					8.8	3.9	5.3	3.9	5.0
901134	VALLEY GOLF ASSOCIATION	281	RED RIVER OF THE NORTH	74	300	12.3			7.5	10.0	3.0	0.7	3.6	3.4	4.2
901158	SKALET, KEITH M	290	RED RIVER OF THE NORTH	70	500	16.0			8.1						
901191	FURUSETH BROTHERS	290	RED RIVER OF THE NORTH	40	850	18.0									
901191	FURUSETH BROTHERS	290	RED RIVER OF THE NORTH	40	850	18.0									
901191	FURUSETH BROTHERS	290	RED RIVER OF THE NORTH	40	850	18.0									
901333	BREKKE BROTHERS INC	290	RED RIVER OF THE NORTH	230	1150	25.0			8.0	22.2	25.0		3.0		
911251	W K E FARMS INC	290	RED RIVER OF THE NORTH	138	800	23.0				15.8	9.0	8.0	20.0	5.0	21.0
911276	BURD, DOUGLAS J	290	RED RIVER OF THE NORTH	60	1000	5.0					3.0				
921200	W K E FARMS INC	290	RED RIVER OF THE NORTH	140	800	14.0						10.0	1.0	7.0	12.0
921218	CAMPBELL, ADELAIDE	290	RED RIVER OF THE NORTH	160	800	19.3					1.7	0.6	1.8	2.7	
931177	MALLINGER BROTHERS	290	RED RIVER OF THE NORTH	80	400	10.0							2.1		
931254	BURD, DOUGLAS J	290	RED RIVER OF THE NORTH	59	550	16.6						2.5			
941144	SCOTT W KNUTSON INC	290	RED RIVER OF THE NORTH	65	500	10.6									
951080	PETERSON, DOUGLAS	290	RED RIVER OF THE NORTH	99	800	6.3									

Minnesota DNR Water Appropriation Use Codes:

 Municipal
 211

 Steam power cooling-once through
 222

 Agricultural processing (food & livestock)
 241

 Golf course
 281

 Landscaping
 283

 Major crop irrigation
 290

 Wild rice irrigation
 296

North Dakota State Water Commission Use Codes:

 Irrigation
 IR

 Fish and Wildlife
 FW

 Municipal
 MU

 Industrial
 ND

 Recreation
 RE

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North Dakota Permitted Users

	NOITH DAKOTA FEITHILLEG USER																	
				Water	Use Appropr	iation				Ar	nnual Re	ported	Water l	Jse (ac-	ft)			
Name	Permit Number	County	Source	ac-ft	acre	gpm	Use *	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	
U.S. FISH AND W	4594	Barnes	Sheyenne River	2208.5	0	2394	FW	i i										
U.S. FISH AND W	4595	Barnes	Sheyenne River	1193.5	0	1750												
U.S. FISH AND W	4595	Barnes	Sheyenne River	1193.5	0	1750	FW											
BARNES COUNTY W	4126	Barnes	Sheyenne River	46.4	0		FW											
BARNES COUNTY W	4126	Barnes	Sheyenne River	46.3	0	0	FW											
PFINGSTEN, ORVI	3605	Ransom	Sheyenne River	390	305	2400	IR	392.2	287	203.1	71.5	146.7	203.8	367	381.3	377.5	62.5	
EVANSON, ROGER	2411	Ransom	Sheyenne River	470.8	369.7	2250	IR	344.4	245.7	308.7	266	158.7	32.4	141.7	189.3	189.7	79.8	
MYRON, DUANE R.	4670	Grand Forks	Red River	600	943.1	2100	IR					48.2	45.5	51.9	198.1	40.2		
MERRILL, AARON	4364	Traill	Red River	396	267.4	2000	IR		0	0	110	28.1	36.7	62.4	0			
BUNDE, DAVID	4685	Grand Forks	Red River	559.2	372.8	2000	IR						44.7	68.9	18.8	44.7	0	
GALEGHER FARMS,	4873	Grand Forks	Red River	447.6	298.4	1600	IR								0	0	0	
SCHUMACHER, JOH	4325	Walsh	Red River	273.6	273.6	1500	IR		0	0	0	0	0	0	0			
SCHUMACHER, JOH	4325	Walsh	Red River	273.6	273.6	1500	IR		65	33	4	16.2	40.4	18.3	17.7			
HUGHES, PATRICK	4693	Grand Forks	Red River	293	234.5	1500	IR						18.9	16.4	23.7	12.7		
SCHUMACHER, JOH	4325	Walsh	Red River	273.6	273.6	1500	IR							0	0			
KASOWSKI, MARK	5115	Cass	Sheyenne River	11.5	20	1400	IR								2.9			
KASOWSKI, MARK	3779	Cass	Sheyenne River	32	23.6	1400	IR	9.4	9	5.2	3	3	6.5	9.3	7.1	1.5	0.4	
KASPARI, DAVID	2710	Ransom	Sheyenne River	323	275.8	1300	IR	0	0	300.5	127.4	35.4	0	0	0	121.9		
KASPARI, DAVID	2710	Ransom	Sheyenne River	323	275.8	1300	IR	334.1	492.1	0	127.4	0	0	66.7	90.8	0		
FROEMKE, ARGIL	757	Ransom	Sheyenne River	161	128.5	1200	IR	209.9	120	221	317.6	87.5	0	14.3	51.7	95.7	150	
FARGO PARK DIST	4145	Cass	Red River	350	171	1200	IR	0	20	110	23	140	106.7	120				
MERRILL, AARON	4328	Traill	Red River	301.5	201	1200	IR		198	130.5	38.5	25.3	36.2	5.7	0			
GOWAN, CHARLES	1048	Grand Forks	Red River	87.9	87.9	1150	IR	134	167.6	40	14.7	0	0	0	0	0	0	
OXBOW COUNTRY C	2059	Cass	Red River	155	103	1150	IR	125.2	212	91	119.7	122.8	140.4	73.7	109.2	124.8	114.4	
FRIESE, RONALD	698	Ransom	Sheyenne River	153.2	101.6	1054.2	IR	183	0	292.3	166	34.7	0	317.7	93.8	148.1	163	
FRIESE, RONALD	698	Ransom	Sheyenne River	143.8	95.4	1054.1	IR	0	87.6	0	0	0	0	0	0	0	0	
HATFIELD, JANIC	1610	Benson	Sheyenne River	52.5	42	1000	IR	0	0.5	25	16.7	12.5	20.8	0	8.3	13.3	13.3	
HATFIELD, JANIC	1610	Benson	Sheyenne River	10	8	1000	IR	0	0	0	0	0	0	0	0	0	0	
HATFIELD, JANIC	1610	Benson	Sheyenne River	0	0	1000		0	0	0	0	0	0	0	0	0	0	
QUAL GRAIN	3614	Ransom	Sheyenne River	278	139	1000	IR	41.7	83.5	71.6	51.7	52.4	0	70	75	24.9	43.1	
MYRON, DUANE R.	4332	Grand Forks		204	136	1000				46.1	36.8	0	13.7	0	0	21.4		
ALTENDORF, MART	4190	Walsh	Red River	187.5	150	900		71.6	91.6	0	2	33.8	25	25	37.5			
LECLERC, RAY	4380	Grand Forks	Red River	26.6	13.3	900					0	11.4	0	0	0	0	0	
MESSNER, DOUGLA	4999	Nelson	Sheyenne River	265.9	177.3	900								0				
ROTENBERGER, RO	02424C	Ransom	Sheyenne River	122	94.3	805		110.5	63	44.2	0	0	0	0	0	0	0	
GOWAN, CHARLES	1046	Grand Forks	Red River	25	12.5	800		0	0	0	0	0	0	0	0	0	0	
GOWAN, CHARLES	1046	Grand Forks	Red River	25.2	12.6	800		0	0	0	29.2	0	0	18.8	0	0	0	
GOWAN, CHARLES	1046	Grand Forks	Red River	99.8	49.9	800		0	0	0	0	31.3	16.8	6.3	9.4	0	0	
PFINGSTEN, MONI	4650	Ransom	Sheyenne River	136.5	91	800							16.9	35.7	41.3	62.5	373.1	
FRIESE, RONALD	3715	Ransom	Sheyenne River	165	110	800		0	0	0	0	2.9	0	8	0	8.4	6.3	
MCRITCHIE, ROBE	4780	Ransom	Sheyenne River	156.8	104.5	800									60.5	89.7		
SONDREAL FARMS,	4226	Grand Forks	Red River	158	105.8	800				0	0	0	0	0	0	0		
GRZADZIELEWSKI,	4282	Walsh	Red River	136.8	136.8	800		40.3	17.9	5	21.2	17.7	19.8	8.6				
GRZADZIELEWSKI,	4335	Walsh	Red River	136.8	136.8	800		40.3	35.8	0	0	17.7	0	8.6				
THOMPSON, G & B	4403	Pembina	Red River	198	248	800		79.6	16.7	7.4	7.6	0	0	15.5				
GOWAN, CHARLES	4434	Grand Forks	Red River	140	140	800				22.1	32.9	0	0	0	0	0		
THOMPSON, DENNI	4774	Grand Forks		252	168	800								35	32.1	23.2		
THOMPSON, DENNI	4773	Grand Forks	Red River	237	158	800								9	27.5	0		
EVANSON, ROGER	4747	Ransom	Sheyenne River	173.1	115.4	800									73.4	75.4	16.8	
LOYLAND, ART JR	4887	Grand Forks	Red River	244	163.4	800					7.7	0	0					
SUNSET MEMORIAL	4963	Cass	Red River	60	30	750							0					
STOFFEL, PETER	3606	Ransom	Sheyenne River	209.4	139.6	700		0	0	0	36	29.2	0	20.8	46.3	83.3	33.8	
BUNDE, ARDELL T	4143	Grand Forks	Red River	250	200	700	IR		8.5	4.7	0	16.3	17.2	5.1	50	39		

IR = Irrigation
FW = Fish and Wildlife
MU = Municipal

ND = Industrial

RE = Recreation

North Dakota Permitted Users

Notifi Dakota Fermitteu Oser																		
Water Use Appropriation						iation			Annual Reported Water Use (ac-ft)									
Name	Permit Number	County	Source	ac-ft	acre	gpm	Use *	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	
BUNDE, ARDELL T	4143	Grand Forks	Red River	274.4	219.5	700	IR			87.4	76.7	40	0	30.1	43.7	11.3	С	
GALDE, LLOYD	607	Nelson	Sheyenne River	54	43.3	650	IR	0	0	0	0	0	0	0	0	0		
GALDE, LLOYD	607	Nelson	Sheyenne River	66	53	650	IR	0	0	43.8	0	0	0	0	0	0		
HIEB, JERRY	01976A	Barnes	Sheyenne River	148	118	610	IR	98.3	79	0	39.3	0	39.3	39.3	39.3	29.5	0	
GRAND FORKS COU	1081	Grand Forks	Red River	90	65	600	IR	77.6	136	95.3	82.2	51.9	65	68.7	92.9	64.9	C	
FRIESE, RONALD	1241	Ransom	Sheyenne River	138.3	169.5	600		113.2	113.2	130.3	87.8	13.5	0	30.3	20.7	16.3	0	
FRIESE, RONALD	1241	Ransom	Sheyenne River	138.3	169.4	600	IR	183	176.4	301.6	166	47.3	0	146.1	42.8	24.6	138.2	
HAKANSON, DONAL	1611	Benson	Sheyenne River	38.6	30.8	600	IR	0	0	0	0	0	0	0	0	0		
HAKANSON, DONAL	1611	Benson	Sheyenne River	9.5	7.6	600	IR	0	0	0	0	0	0	0	0	0		
HAKANSON, DONAL	1611	Benson	Sheyenne River	8	6.4	600		0	0		0	0	0	0	0	0		
HAKANSON, DONAL	1611	Benson	Sheyenne River	28.4	22.7	600	IR	0	0	0	4.2	0	0	0	0	0		
HAKANSON, DONAL	1611	Benson	Sheyenne River	39.5	31.6	600	IR	0	0	0	0	0	0	0	0	0		
LAMBRECHT, ALLE	2296	Ransom	Sheyenne River	118	76.4	600	IR	12.7	0	0	0	0	0	13.3	0	0	0	
FARGO PARK DIST	3857	Cass	Red River	50	30.7	600		20	31.6		45.7	44.2	51.6	25.8				
FARGO PARK DIST	3857	Cass	Red River	50	30.8	600		80	88.4	84.8	88	87.9	107.5	86.2				
FARGO COUNTRY C	796	Cass	Red River	65	65	550		110	81.7	76.7	67.5	56.5	18.7	16.8	0	16.3	36	
J.O. THORSON FA	4001	Grand Forks	Red River	100	100	500	IR	18.4	0	43.8	0	5.4	6	0	0	0		
CAMPBELL, THOMA	4740	Grand Forks		82.6	82.6	500								0	0	0	0	
GRAND FORKS PAR	4385	Grand Forks	Red River	210	140	475				0	0	0	0	0	0	0		
TOWN & COUNTRY	592	Barnes	Sheyenne River	43.3	28.9	450		26.5	26		15.6	19.9	6.6	6.6	6.6	6.6	6.6	
JENNER, FRANCES	1089	Cass	Sheyenne River	3	3	450		0	0		0	0	0	3.8	2.5	1.3	0	
JENNER, FRANCES	1089	Cass	Sheyenne River	9.7	9.7	450		13.7	6.7	12.5	3.8	3.8	0	0	0	0	0	
JENNER, FRANCES	1089	Cass	Sheyenne River	9.8	9.8	450		0	0		0	0		0.7	0	2	0	
WENDEL, RUDY	1573	Barnes	Sheyenne River	7.5	5	450		0	0	0.3	0	0	0	0	0	0	0	
LAMBRECHT, ALLE	2012	Ransom	Sheyenne River	25.6	25.6	450		37.7	24.4	0	0	0	0	0	0	0	0	
LAMBRECHT, ALLE	2012	Ransom	Sheyenne River	84	84	450		0	0	0	0	0	0	0	0	0	0	
KREBSBACH, MARK	2206	Eddy	Sheyenne River	75	75	450		46.7	46.7	68.4	23.9	71.6	0	33.1	15.6	0	0	
RIVERSIDE CEMET	4015	Cass	Red River	45	24.1	400			0	0	0	0	0	0	0	0	12.5	
RIVERSIDE CEMET	4015	Cass	Red River	45	24.2	400			90	90	90	90	0	0	4	0	0	
BUNDE FARMS	4348	Grand Forks	Red River	73.6	58.5	400					25	19.2	0	19	18.3	18.3	27.5	
BUNDE FARMS	4348	Grand Forks		73.7	58.5	400					10	0	0	0	0	0	0	
BUNDE FARMS	4348	Grand Forks	Red River	73.7	58.5	400					0	0	0	0	0	0	0	
GOWAN, CHARLES	4435	Grand Forks	Red River	126	124	400				0	0	0	0	0	0	0		
GOWAN, CHARLES	4435	Grand Forks		126	128	400				0	0	0	0	0	11.3	6.9		
GOWAN, CHARLES	4736	Walsh	Red River	73.4	73.4	400								0	0	0	0	
GOWAN, CHARLES	4736	Walsh	Red River	211	211	400							0	0	0	0		
GRAND FORKS PAR	01305P	Grand Forks	Red River	119.6	95.7	350		119.3	91.5	88.4	71.3	71.7	62	61.5	56.6	75.9	73.7	
LUNDEBY, IVER G	1889	Nelson	Sheyenne River	20	30	350		0.5	0.5	1.5	1.3	0.6	0	0	0	0	0	
JOHNSON, ALDEN	4189	Cass	Sheyenne River	36	18	325				0	0	0	0	0	0	0	0	
JOHNSON, ALDEN	4189	Cass	Sheyenne River	36	18	325				0	0	0	0	0	0	0	0	
WEISENHAUS, GLE	3756	Ransom	Sheyenne River	55	30	300		0	0		0	0	0	55.2	15	37.5	25	
WEISENHAUS, GLE	3756	Ransom	Sheyenne River	55	30	300		35	46		35	15	0	0	0	0	0	
VALLEY CITY STA	629	Barnes	Sheyenne River	16	11	299.2		14.1	3	10.2	7.2	4.8	3	3.6	1.7	1.8	1.5	
HIEB, JERRY	1976	Barnes	Sheyenne River	43	35	296.7		105	122.1	0	52.5	17.2	17.2	23.3	23.3	29.2	0	
HIEB, JERRY	1976	Barnes	Sheyenne River	99	79	296.7		0	0	0	0	0	0	6.8	3.3	3.3	0	
HIEB, JERRY	1976	Barnes	Sheyenne River	73	58	296.6		0	0	0	0	0	2.1	5.8	5.8	5.8	0	
GOWAN, CHARLES	4689	Walsh	Red River	93.6	93.6	266.7		1					0	0	0	0	0	
GOWAN, CHARLES	4689	Walsh	Red River	94.8	94.8	266.7		1					0	0	0	0	0	
GOWAN, CHARLES	4689	Walsh	Red River	64.1	64.1	266.6							0	0	0	0	0	
RANEY, ROBERT	1342	Pembina	Red River	61.5	161.3	256		0	0	0	0	0	0	0	0	0		
RANEY, ROBERT	1342	Pembina	Red River	61.4	161.3	256		0	0		0	0		0	0	0		
LOBERG, LESLIE	515	Cass	Sheyenne River	4.6	3.7	225		3	3.8		5.1	5.5		0	0	0		
OAK IRRIGATION	641	Ransom	Sheyenne River	1	1	225	IR	4.2	1.3	1.3	1.3	0.8	0.6	0.5	1	1	0.7	

IR = Irrigation
FW = Fish and Wildlife
MU = Municipal

ND = Industrial

RE = Recreation

North Dakota Permitted Users

	NOTHI DAROLA PETITILLEU USEIS																
				Water	Use Approp	riation		Annual Reported Water Use (ac-ft)									
Name	Permit Number	County	Source	ac-ft	acre	gpm	Use *	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
HOENHOUSE, HARV	2011	Ransom	Shevenne River	36	36	225	IR	0	0	0	0	0	0	0	0	0	
HOENHOUSE, HARV	2011	Ransom	Shevenne River	46		225		0	0	30.4	43	8	0	5.5	0	0	
HOENHOUSE, HARV	2011	Ransom	Shevenne River	44.8		225		0	0		0	0		0	0	0	
HOENHOUSE, HARV	2011	Ransom	Shevenne River	12		225		0	0	0	0	0	0	0	0	0	
SCHOLZ, EARL W.	2358	Cass	Shevenne River	3.4		224		2.2	2.5	0.8	2.8	0	0	0.2	1.2	0.6	(
RIVERTREE RAINM	4210	Cass	Shevenne River	30		220		12.3	24.1	12.7	4.3	8.6	4.8		10.7		
BROWN, LARRY	454	Grand Forks	Red River	26.1	26.1	200	IR	2	2	2.3	1.4	0	0	0	0	0	C
FARGO PARK DIST	3561	Cass	Red River	33.4	22.3	200		7	7	7	7	7	11.3	22.1	33.1	41.4	19.3
ALL SEASONS GAR	4899	Grand Forks	Red River	20	10	200	IR							0	0	0	
ORR, STEVE	788	Cass	Red River	0.5	1.5	168.3	IR	0	0	0	0	0	0	0	0	0	
ORR, STEVE	788	Cass	Red River	0.5	1.5	168.3	IR	0	0	0	0	0	3	0.7	0	0	
BOIS DE SIOUX G	3008	Richland	Red River	5	11.4	166.7	IR	19.2	13.6	14.6	14.5	13.4	8.2	10.6	11.3	11.1	8
BOIS DE SIOUX G	3008	Richland	Red River	5	35.7	166.7	IR	0	0	0	0	0	0	0	0	0	C
HILL, OLIVE I.	4123	Cass	Red River	8.5	4.2	160	IR			5	5	5	5	5	5	5	C
LISBON BISSELL	1227	Ransom	Sheyenne River	10	49.1	155	IR	39	38.3	20.4	37.6	33.8	14.7	23.6	7.3	73.7	58.9
KREBSBACH, MARK	3246	Eddy	Sheyenne River	25	11	150	IR	0	0	0	0	0	0	0	2.3	0	C
VALLEY CITY STA	629	Barnes	Sheyenne River	8	5	149.6	IR			1.6	0.8	1.2	1	1	1.1		
WAGAR NURSERY,	240	Barnes	Sheyenne River	20	10	140	IR	2.1	3.2	2.1	1.8	0.7	0	1.5	1.6	0	0.6
RANEY, PHILIP C	01342C	Pembina	Red River	31.1	81.6	129.5	IR	0	0	0	0	0	0	0	0	0	
RANEY, PHILIP C	01342C	Pembina	Red River	31.1	81.6	129.5	IR	0	0	0	0	0	0	0	0	0	
RANEY, DAVID R.	01342B	Pembina	Red River	29.5	77.5	123	IR	0	0	0	0	0	0	0	0	0	
RANEY, DAVID R.	01342B	Pembina	Red River	29.5	77.5	123	IR	0	0	0	0	0	0	0	0	0	
GRAND FORKS CO.	4582	Grand Forks	Red River	7	3.5	120	IR								0	0	
CHRISAN COMPANY	839	Cass	Red River	3	3	100	IR	0	0	0	0	0	0	0	0	0	C
CHRISAN COMPANY	839	Cass	Red River	11.9	11.9	100	IR	1.3	0	0	0	0	0	0	0	0	(
SISTERS OF MARY	2198	Barnes	Sheyenne River	1.7	1.7	100	IR	0	3.8	2.4	0.1	0.7	0	0.8	3.3	3.6	3.4
SISTERS OF MARY	2198	Barnes	Sheyenne River	5.3	5.3	100		4.7	0			0.1	0	0	0	0	C
INGSTAD, ROBERT	00653A	Barnes	Sheyenne River	16.1	13		IR	16	16			16	16	16	16	16	16
EMANUELSON, RAN	01342A	Pembina	Red River	15.3	40	63.5		0	0			0	Ŭ	0	0	0	
EMANUELSON, RAN	01342A	Pembina	Red River	15.2	40	63.5		0	0				0	0	0	0	
RANEY, DAVID R.	01342D	Pembina	Red River	15.3	40	63.5		0	0				0	0	0	0	
RANEY, DAVID R.	01342D	Pembina	Red River	15.2	40	63.5		0	0			,	Ŭ	0	0	0	
RANEY, PHILIP C	01342E	Pembina	Red River	14.6		63.5		0	0					0	0	0	
RANEY TRUST, RO	01342G	Pembina	Red River	15.2		63.5		0	0				Ŭ	0	0	0	
RANEY TRUST, RO	01342G	Pembina	Red River	15.2	40	63.5		0	0				U	0	0	0	
BLACK, SUSAN	01342H	Pembina	Red River	15.2		63.5		0	0					0	0	0	
BLACK, SUSAN	01342H	Pembina	Red River	15.2	40	63.5		0	0				Ŭ	0	0	0	
EMANUELSON, RAN	01342J	Pembina	Red River	15.2	40	63.5		0	0					0	0	0	
EMANUELSON, RAN	01342J	Pembina	Red River	15.3	40	63.5		0	0		0	0	0	0	0	0	
ROWEB IRRIGATIO	397	Ransom	Sheyenne River	1	1		IR	1	1		1	1	1	1	1	1	
RANEY, PHILIP C	01342E	Pembina	Red River	14.7	38.5		IR	0	0	0	0	0	0	0	0	0	
LONGTIN, TERRY	00617C	Grand Forks	Red River	9.9		53.9				_		_					
BOIS DE SIOUX G	3008	Richland	Red River	1.6		53.1		0	0					0	0	0	(
RANEY, DAVID R.	01342F	Pembina	Red River	11.9		49.4		0	0					0	0	0	
RANEY, DAVID R.	01342F	Pembina	Red River	11.8		49.4		0	0				Ŭ	0	0	0	
LOGAN, TIMOTHY	00507B	Barnes	Sheyenne River	2			IR	0.1	0		0.1	0.1		0.1	0.1	0.1	0.1
LOGAN, TIMOTHY	00507B	Barnes	Sheyenne River	1.5		7.3		0	0.4					0	0	0	
QUAL GRAIN	3614	Ransom	Sheyenne River	0			IR IR	+	0								1
QUAL GRAIN	3614	Ransom	Sheyenne River	0			IR IR	1	0					1		1	1
THOMPSON, G & B	4403	Pembina	Red River		Ŭ			0									1
THOMPSON, G & B	4403	Pembina	Red River	100500	ŭ		IR	0	40400.5	v		4000000	V	40000	40070 -	44500 -	44000
FARGO, CITY OF	749	Cass	Red River	109500	0	67320		14589.4	13436.5						12373.7		11629.8
GRAND FORKS, CI	835	Grand Forks	Kea River	33600	0	33660	MU	784.1	1072	1939.1	2331.1	3553.5	2112	2072.9	1740.7	1427	1180.1

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North Dakota Permitted Users

				Water	Use Appropri	iation			Annual Reported Water Use (ac-ft)								
Name	Permit Number	County	Source	ac-ft	acre		Use *	1988	1989	1990	1991	1992		1994	1995	1996	1997
FARGO, CITY OF	1091	Cass	Sheyenne River	17940	0	24235.2	MU	0	0	0	0	0	0	0	0	0	0
FARGO, CITY OF	1091	Cass	Shevenne River	17940	0	24235.2	MU	282.2	458.7	0	0	1413.9	4515	1179.1	0	0	0
VALLEY CITY, CI	1096	Barnes	Shevenne River	6686	0	13464	MU	1225	1083.6	950.4	1001.2	828	835.3	858.2	888.6	903.9	894
FARGO, CITY OF	4718	Cass	Shevenne River	7000	0	11250	MU								1374.5	326.5	0
GRAND FORKS, CI	00835A	Grand Forks	Red River	20023	0	2500	MU				0	0	0	0	0	0	0
DRAYTON, CITY O	669	Pembina	Red River	1000	0	1000	MU	122.3	142	289.5	256.2	228.3	207.5	185.3	231.2	200	203
GRAFTON, CITY O	893	Walsh	Red River	432.2	0	700	MU	759.5	757	838.2	743.7	753.2	456.1	0	0	0	0
GRAFTON, CITY O	893	Walsh	Red River	432.2	0	700	MU	0	0	0	0	0	0	0	0	0	0
GRAFTON, CITY O	893	Walsh	Red River	432.2	0	700	MU	0	0	0	0	0	0	889.8	912.1	755.8	782.9
WEST FARGO, CIT	921	Cass	Sheyenne River	954	0	700	MU	52.5	0	0	0	0	0	0	0	0	0
WEST FARGO, CIT	00921A	Cass	Sheyenne River	1460	0	700	MU	0	0	0	0	0	0	0	0	0	0
LISBON, CITY OF	3588	Ransom	Sheyenne River	373	0	600	MU	2.4	1.7	1.4	2	2.9	3.2	3.2	1.5	1.6	0.9
PEMBINA, CITY O	4054	Pembina	Red River	154	0	400	MU		63	57.4	44.9	83.6	80.5	86.5	87.6	82.9	81.5
DRAYTON, CITY O	669	Pembina	Red River	0	0	0	MU	0	0	0	0	0	0	0	0		
BALDHILL MISC.	682	Barnes	Sheyenne River	0	0	0	MU										
DRAYTON, CITY O	1244	Pembina	Red River	500	0	0	MU	0	0	0	0	0	0	0	0	0	0
DRAYTON, CITY O	1244	Pembina	Red River	500	0	0	MU	122.3	142	289.5	0	0	0	0	0	0	0
GRAND FORKS, CI	4354	Grand Forks	Red River	422	0	0	MU			3298.2	0	0	0	0	0	0	
AMERICAN CRYSTA	1076	Pembina	Red River	2250	0	6600	ND	696.5	810.2	647.7	557.1	238.6	917.7	122.8	107.4	238.6	461.4
CARGILL INCORPO	4861	Richland	Red River	6000	0	4000	ND								0	327.1	1771.3
AMERICAN CRYSTA	251	Cass	Red River	1841	0	3455.7	ND	0	74	90.5	0	24.5	0	0	19.3	0	0
SHEYENNE SAND &	775	Eddy	Sheyenne River	1000	0	1570.8	ND	270.9	233	282.3	292.8	258	270.3	305.3	145.8	140.2	197
GUTZMER CONSTRU	913	Ransom	Sheyenne River	26.5	0	1500	ND	21.5	20.1	14.6	19	24.3	21.2	20.7	20	17.5	19.3
WEST FARGO, CIT	127	Cass	Sheyenne River	200	0	450	ND	0	0	0	0	0	0	0	0	0	0
WINTER SPORTS L	2795	Ransom	Sheyenne River	130	0		ND	78.2	25	37.6	39.4	46.3	0	0	4	11.1	5.9
AMERICAN CRYSTA	251	Cass	Red River	0	0	0	ND	0	0	0	0	0	0	0	0	0	0
SHEYENNESAND &	775	Eddy	Sheyenne River	0	0		ND	0	0	0	0	0	0	0	0	0	0
GUTZMER CONSTRU	913	Ransom	Sheyenne River	0	0	0	ND	0	0	0	0	0	0	0	0	0	0
AMERICAN CRYSTA	1076	Pembina	Red River	0	0	0	ND	0	0	0	0	0	0	0	0	0	0
U.S. FISH AND W	1855	Barnes	Sheyenne River	235	0	3500											
U.S. FISH AND W	1855	Barnes	Sheyenne River	235	0	3500	RE										
U.S. FISH AND W	416	Barnes	Sheyenne River	210.5	0	2244	RE										
U.S. FISH AND W	400	Barnes	Sheyenne River	115	0	1750	RE										
U.S. FISH AND W	400	Barnes	Sheyenne River	115	0	1750											
WELLS COUNTY WA	1349	Wells	Sheyenne River	600	0	0	RE										

North Dakota Use Codes:

Irrigation
Fish and Wildlife IR FW Municipal MU Industrial ND RE Recreation

IR = Irrigation FW = Fish and Wildlife MU = Municipal

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ndusers1.xls

	Manitoba Permitted Water Users		
NAME	ADDRESS	PURPOSE	WORKS LOCATION
Sorin, Jean		Domestic	R. L. 496, Parish of Ste. Agathe
Gateway Industries Ltd.		Industrial	R. L. 17, Parish of St. John
Manitoba Hydro	P.O. Box 815, Winnipeg, MB, R3C 2P4, Canada	Industrial	73 River Lot, St Clements
Manitoba Hydro	P.O. Box 815, Winnipeg, MB, R3C 2P4, Canada	Industrial	73 River Lot, St Clements
Winnipeg, The City of	2799 Roblin Boulevard, Winnipeg, MB, R3R 0B8, Canada	Industrial	Amy Street,
Manitoba Sugar Co.	27 00 1100 mil Douistara, 1711 mipog, mb, 11011 020, oanaaa	Industrial	Lots 18-23, Parish of St. Vital
Building Products Ltd.		Industrial	20 River Lot, St John
Valley's Edge Produce		Irrigation	86 River Lot, Ste Agathe
Winnipeg, The City of	2799 Roblin Boulevard, Winnipeg, MB, R3R 0B8, Canada	Irrigation	P. L. 18-24, Parish of Kildonan
Winnipeg, The City of	2799 Roblin Boulevard, Winnipeg, MB, R3R 0B8, Canada	Irrigation	P. L. 19. Parish of St. Vital
Parisien. Paul	2700 Robini Bodiovara, Willingog, WD, Roix 050, Odridad	Irrigation	R. L. 227. Parish of St. Norbert
Fontaine Farms Ltd.		Irrigation	R. L. 153-155, Parish of Ste. Agathe
Heinrichs, Dwight Peter & Eugene Charles		Irrigation	135 River Lot, Ste Agathe
McLeod, Jerry Roy & Bonnie Barbara		Irrigation	617 River Lot, Ste Agathe
Kostal, John & Carolyn		Irrigation	R.L. 468, 470, 472, 474 & 476, Parish of Ste. Agathe
Petrie, Brian William		Irrigation	R. L. 619, Parish of Ste. Agathe
Searle Greenhouses Ltd.		Irrigation	R. L. 78-85, Parish of St. Clements
Wiens, Theodor & Daniel		Irrigation	R. L. 217, Parish of St. Norbert
Houle Farms Ltd.		Irrigation	R.L. 127-130, Parish of Ste. Agathe
Alty, J. S. R.	126 Buxton Road, Winnipeg, MB, R3T 0G9, Canada	Irrigation	638 River Lot, Ste Agathe
Blatta, J., L. & C.	126 Buxton Road, Willingeg, MB, RST 069, Canada	Irrigation	R.L. 488, Parish of Ste. Agathe
Barnabe, G.		Irrigation	R.L. 482, Parish of Ste. Agathe
McDonald, M. & C.		Irrigation	R. L. 47. Parish of St. Norbert
Cenerini, R. & C.		Irrigation	R. L. 186, Parish of St. Norbert
Riverview Golf & Country Club			343 River Lot, Ste Agathe
Devos, D. & M.		Irrigation Irrigation	R. L. 282-286, Parish of St. Andrews
Southwood Golf and Country Club			R. L. 7
		Irrigation	R. L. 110. Parish of St. Pauls
Schwabe, J. A. G. & D. E.		Irrigation	-,
Eidse, G. L. & H. E.		Irrigation	R. L. 417, Parish of Ste. Agathe
Cenerini, R.		Irrigation	R. L. 41, Parish of Ste. Agathe
Meyer, J.		Irrigation	R. L. 205, Parish of St. Norbert
Fox, C. J.		Irrigation	R. L. 189, Parish of St. Peter
Addis, T. S.		Irrigation	27 River Lot, St Paul
Norquay, I. P.		Irrigation	R. L. 21, Parish of St. Clements
Leclair Freres Ltee.		Irrigation	R. L. 134-137, Parish of Ste. Agathe
Lafond, N. O.		Irrigation	R. L. 274 & 276, Parish of Ste. Agathe
Fontaine, J. R. G.		Irrigation	R. L. 153-155, Parish of Ste. Agathe
Cybulsky, K. A.		Irrigation	R. L. 104, Parish of St. Clements
Canada - Agriculture (Glenlea Research Station)		Irrigation	3 River Lot, St Norbert
St. Boniface General Hospital		Irrigation	83 River Lot, St Boniface
Middlechurch Home, etc.		Irrigation	18 River Lot, St Paul
Reimer, D. S.		Irrigation	39 River Lot, St Vital
Searle Greenhouses Ltd.		Irrigation	R. L. 78-85, Parish of St. Clements
Mudry, N. & A.		Irrigation	R. L. 58, Parish of St. Norbert
Woytowicz, P.		Irrigation	R. L. 63, Parish of St. Norbert
Loganberg, R. B. & A. J.		Irrigation	R. L. 1, Parish of St. Pauls
Glen Eden Memorial Gardens		Irrigation	Lots 38-45, Parish of St. Pauls
Phippen, J. W.		Irrigation	R. L. 167-169, Parish of St. Norbert
Praznik, B.		Irrigation	R. L. 70, Parish of St. Andrews
Canada - Agriculture (Glenlea Research Station)	, , MB, , Canada	Irrigation	3 River Lot, St Norbert
Yablonski, J. T. & G. Y.		Irrigation	R. L. 248, Parish of St. Andrews
Shupena, E. S. & R. S.		Irrigation	R. L. 585, Parish of Ste. Agathe
Shale, H. J.		Irrigation	R. L. 186, Parish of St. Andrews
Mudry, N. & A.		Irrigation	R. L. 58, Parish of St. Norbert

Manitoba Permitted Water Users								
NAME	ADDRESS	PURPOSE	WORKS LOCATION					
Daman, J., C. & W.		Irrigation	R. L. 160 & 161, Parish of St. Norbert					
Woytowicz, P.		Irrigation	R. L. 63, Parish of St. Norbert					
The Metropolitan Corporation of Greater Winnipeg (Crescent Drive Golf Course)	, , MB, , Canada	Irrigation	29 River Lot, St Vital					
The Metropolitan Corporation of Greater Winnipeg (Kildonan Golf Course)	, , MB, , Canada	Irrigation	18 River Lot, Kildonan					
Loganberg, R. B. & A. J.		Irrigation	R. L. 1, Parish of St. Pauls					
Gayner, J. R. & B. T.		Irrigation	R. L. 113, Parish of St. Pauls					
Pritchard, H. T. & M.		Irrigation	R. L. 112, Parish of St. Pauls					
Sokolowski, Victor		Irrigation	R. L. 282-284, Parish of St. Andrews					
Topor, Charlie		Irrigation	R. L. 275 & 276, Parish of St. Andrews					
Kaminski, W.		Irrigation	R. L. 277-279, Parish of St. Andrews					
Shale, H. J.		Irrigation	R. L. 186, Parish of St. Andrews					
Canada - Agriculture (Glenlea Research Station)		Irrigation	3 River Lot, St Norbert					
Praznik, B. J. & M. H.		Irrigation	R. L. 71, Parish of St. Andrews					
Praznik, Thomas & Rose		Irrigation	R. L. 78, Parish of St. Andrews					
University of Manitoba (Glenlea Research Station)		Irrigation	6 River Lot, St Norbert					
Nisbet, Donald A.		Irrigation	NW35-11-4E					
Campeau, Eva		Irrigation	Lot 193, Parish of St. Norbert					
Gibson, James & Connery, Edward J.		Irrigation	160 River Lot, St Norbert					
Connery, James & Dorothy		Irrigation	157 River Lot, St Norbert					
Scott, Gordon		Irrigation	R. L. 68 & 69, Parish of St. Pauls					
Richardson Stock Farms Ltd.		Irrigation	R. L. 197, Parish of St. Norbert					
Manitoba Rugby Union	1700 Ellice Avenue, Winnipeg, MB, R3H 0B1, Canada	Irrigation	148 River Lot, St Norbert					
James Alty and Joan Alty	Box 1, Group 10, R.R. No. 1, St. Norbert, MB, R3V 1L2, Canada	Irrigation	35 River Lot, St Norbert					
Bullet Development Ltd.	7 Killarney, Winnipeg, MB, R3T 5T5, Canada	Irrigation	46 River Lot, St Norbert					
Selkirk, Town of		Municipal	E of Eveline St at Rosser Ave, Selkirk					
Selkirk, Town of		Municipal	E of Eveline St at Rosser Ave,					
Manitoba Water Services Board	2022 Currie Blvd., Brandon, MB, R7A 5Y6, Canada	Municipal	241 River Lot, Ste Agathe					
Winnipeg, The City of	2799 Roblin Boulevard, Winnipeg, MB, R3R 0B8, Canada	Other	108 River Lot, St Norbert					
Ducks Unlimited	Box 1160, Stonewall, MB, R0C 2Z0, Canada	Waterfowl Conservation	R. L. 78, Parish of St. Peter					

Appendix E

Information Summaries Permitted Users

Interview#: 1 Reach/River: Red River

Use: Irrigation **Acres**: 60 **Intake location**: unknown

Description: Sugar beets (three-year **Quantity/Rate/Time of Year**: avg. 2 inches over

rotation) 60 acres during growing season

May 1, 1998—Interviewee indicated that he uses water from the Red River to irrigate his sugarbeet crops. The sugar beets are a rotational crop, planted every three years. According to interviewee, water is used only when necessary; as of late, the years have been wet enough where not much irrigation was needed. Interviewee said that, on average, he uses approximately 2 inches of water over 60 acres, per year. He describes current water quality as good. Interviewee believes that any changes in water quality would hurt his crops, and because his property is considered prime farm land, the loss would be very expensive. He said that if water quality were to change, he would need to stop irrigating; he indicated that he did not see any other alternatives. He was unable to quantify costs of damages and/or solutions. Interviewee is most concerned about possible flooding from an increase in water. [jsf]

Interview#: 2 Reach/River: Red River

Use: Irrigation **Acres**: 250–300 **Intake location**: N/A

Description: Ranges: sunflowers, **Quantity/Rate/Time of Year**: varies depending

legumes, cereals etc. on rainfall

May 1, 1998—Interviewee indicated that she and her husband use water from the Red River for irrigation of crop types that vary every year but include sunflowers, legumes, and cereals. Of their 2,000 acres of farm land, interviewee estimated that 250 to 300 acres is irrigated with water from the river. She was unable to estimate a quantity of water used per year because the amount varies with the rainfall. She said that the quality of the water varied from year to year. According to her, an increase in salinity, sulfates, nitrates, total dissolved solids, hardness, and other similar parameters would probably damage her crops. If changes in water quality were to affect her crops adversely, interviewee indicated that she and her husband would stop irrigating and the costs would be "humongous;" however, she was unable to quantify cost of damages and/or solutions. She indicated that groundwater wells would not be an alternative to river water because the aquifer is too saline. [syh]

Interview#: 3 (has 2 permits) **Reach/River**: Sheyenne River

Use: Irrigation **Acres**: 12-13 **Intake location**: unknown

Description: strawberries **Quantity/Rate/Time of Year**: avg. 3 to 4 inches

over 12 to 13 acres during the growing season

May 4, 1998—Interviewee uses water from the Sheyenne River for the irrigation of 12 to 13 acres of strawberry crops. He said he uses an average of 3 to 4 inches of water over each acre per year. Interviewee has two pumping sites; each pumps 3 gallons per minute into 24 sprinklers per acre. He describes the current water quality as marginal; he has noticed a white crust on the soil caused by hardness and sodium. He has already lost approximately 2 acres, and in other areas the plant density is dropping due to sodium. According to interviewee, pumping water from Devils Lake would not be a problem if it happened infrequently. If the flow from Devils Lake was constant and the water quality changed, interviewee would consider stopping irrigation. He was unable to quantify costs of damages and/or solutions. [jsf]

Interview#: 4 **Reach/River**: Sheyenne River

Use: Irrigation **Acres**: 3–4 **Intake location**: unknown

water yet; permit has appropriated quantity

May 4, 1998—Interviewee indicated that she and her husband were in the process of setting up their irrigation system. As of yet, they have not pumped any water from the Sheyenne River. In the future, they will use water for irrigating 3 to 4 acres of vegetables, including alfalfa. Interviewee said that they have used the water for horses and cattle, as well as recreational swimming, and she considers the water clean. She would be concerned if the water in the Sheyenne were to become saltier, and would stop irrigating. Interviewee was unable to quantify costs of damages and/or solutions. [jsf]

Interview#: 5 **Reach/River**: Sheyenne River

Use: Irrigation **Acres**: 500 **Intake location**: unknown

Description: corn **Quantity/Rate/Time of Year**: reported quantities

to state, on permit information

May 4, 1998—Interviewee uses water from the Sheyenne River to irrigate approximately 500 acres of corn, beans, and alfalfa. He could not cite an average quantity of water used because it varies from year to year depending on precipitation. He said that he reports the quantities to the state and that the information would be on his permit. According to interviewee, the current water quality of the Sheyenne River is very good. He said that when he sends samples to the state before starting irrigation, the state always calls him back to question the water's source because they considered it so pure. According to interviewee, a change in water quality, specifically that of salinity, wouldn't affect his crops. He believes that the salts would be flushed out of the soil and back into the river via the surficial groundwater flow. Interviewee even considers a potential increase in the amount of water in the Sheyenne River to be beneficial. [jsf]

Interview#: 6 Reach/River: Sheyenne River
Use: Irrigation Acres: ? Intake location: unknown

Description: corn and soybean Quantity/Rate/Time of Year: unknown

May 4, 1998—Interviewee uses water from the Sheyenne River for the irrigation of corn and soybean. He did not want to comment on how much water he uses or on what possible impacts might be associated with the pumping of water into the Sheyenne River. [jsf]

Interview#: 7 Reach/River: Red River
Use: Irrigation Acres: unknown Intake location: unknown

Description: potatoes, sugar beets **Quantity/Rate/Time of Year**: unknown

May 4, 1998—Interviewee said that she and her husband use water pumped from the Red River to irrigate potatoes and sugar beets. The amount used in a year depends on precipitation; the state should have records of water use associated with the permit. Interviewee contracts with Simplot for potato crops; Simplot requires 1 inch of water on the crops every week, minus whatever rain falls. Interviewee considers current water quality conditions good. She said that an increase in salinity and hardness would ruin the land, making the soil more alkaline. Interviewee is very concerned about increased alkalinity and said she and her husband would need to stop irrigating if white alkaline spots developed on the land. She believes that surface groundwater is already very alkaline and that it wouldn't be cost-effective to install a deep well because water would be too expensive. Interviewee was unable to quantify costs of damages and/or solutions. She is most concerned about the possible flooding due to the increase in water. [jsf]

Interview#: 8 Reach/River: Red River

Use: Irrigation **Acres**: 250–300 **Intake location**: Glenlea (small town)

Description: Livestock 95% and Irrigation 5% **Quantity/Rate/Time of Year**: up to 1.5 (canola, wheat, barley, corn, flowers, and million gallons in February; once in summer

lawns)

May 4, 1998—According to interviewee, water pumped from the Red River is mainly used for livestock (95 percent), but a small quantity is also used for irrigating crops (canola, wheat, barley, and corn), lawns, and flowers (5 percent). Livestock at the research station consists of approximately 1,000 hogs, 100 dairy cows, and 150 "beef-type" animals. Water pumped from the Red River once during the summer and once in February is stored in a 1- to 1.5-million-gallon reservoir that is typically a third full at the time of pumping. According to interviewee, well water was used at one time, but it was too saline. Interviewee said that the river is currently meeting the research station's needs, and that the water is of good quality. He believes an increase in salinity would cause problems for the animals because they would urinate more, and the salt would also be hard on the equipment. If the water were to become too saline, the research station would have to find another way to get water. He said that groundwater wells are not an option, that it would be too expensive to either truck water in from an outside source or try to connect to a nearby

municipal water supply. Interviewee said that the if the water became too saline, the research center might consider moving to another location. He was unable to quantify costs of damages and/or solutions. [syh]

Interview#: 9 Reach/River: Red River

Use: Irrigation **Acres**: 5 **Intake location**: Winnipeg, about a half-mile from the

flood inlet structure

Description: wide variety **Quantity/Rate/Time of Year**: <0.1 cfs/growing season

May 4, 1998—Interviewee has a permit to take water from the Red River to irrigate approximately 5 acres of crops. He rents the land to local individuals who grow a variety of crops. Water is pumped from the river approximately one-half mile from the flood inlet structure in Winnipeg. Interviewee estimates he pumps less than 0.1 cfs of water during the growing season. He describes current water quality as good; however, he recalled one instance when the sugar plant in North Dakota released a "slug" of something in the water, which caused problems for the fish. Interviewee indicated he does not know what kinds of effects a change in water quality would have on his land, but if he couldn't use water from the river to irrigate, he would have to install wells. According to him, it would be very expensive to install wells that would supply enough water to irrigate the crops. Interviewee was unable to quantify cost of damages and/or solutions. [syh]

Interview#: 10 Reach/River: Red River

Use: Irrigation **Acres:** 50 **Intake location:** East Selkirk

Description: strawberries (may not plant **Quantity/Rate/Time of Year**: unknown

every year)

May 4, 1998—Interviewee said that she and her husband pump water from the Red River to irrigate strawberries. She said that they typically pump the water for irrigation in July and August in the years they plant. Interviewee was unable to quantify a rate or quantity of water pumped and didn't know what effects a change in water quality might have on the crops. [syh]

Interview#: 11 Reach/River: Red River

Use: Irrigation **Acres**: 4,500 **Intake location**: unknown

Description: sugar beets, potatoes, beans **Quantity/Rate/Time of Year**: has not used

water—it created too much conflict

May 5, 1998—According to interviewee, the farm has a permit for withdrawing water from the Red River, but has never actually used it. He said that his neighbors had a problem with it and didn't use it. The farm consists of approximately 4,500 acres of sugar beets, potatoes, beans, and other crops. Although interviewee doesn't use river water to irrigate his crops, he believes that an increase in salinity due to pumping water from Devils Lake into the Sheyenne River would not

affect water quality in the Red River enough to cause any damage. He indicated that by the time the water reached his farms on the Red River, the salt would be diluted enough to not affect the crops. [jsf]

Interview#: 12 Reach/River: Red River

Use: Irrigation **Acres**: 60 **Intake location**: unknown

Description: sugar beets (three-year rotation) **Quantity/Rate/Time of Year**: unknown

May 6, 1998—Interviewee said that she hasn't needed to pump water from the Red River for irrigation of vegetable crops for the past few years because of the heavy amounts of rain. She was unable to quantify the average amount of water that she pumps from the river in a year. She said that she has no concerns about current water quality or the quality if water from Devils Lake were pumped into the Sheyenne River. Interviewee was reluctant to answer questions concerning this issue. [jsf]

Interview#: 13 Reach/River: Red River

Use: Irrigation **Acres**: 3 **Intake location**: unknown

Description: carrots, potatoes, peas **Quantity/Rate/Time of Year**: three times a year,

unknown quantity

May 7, 1998—Interviewees said they use water from the Red River to irrigate approximately 3 acres of carrots, potatoes, and peas. They take water from the river approximately three times a year, but are uncertain about the quantity. They describe current water quality as good and do not know what effects a change in water quality would have on the crops. If problems did arise, the interviewees would have to use a dugout, which has no associated costs. [syh]

Interview#: 14 Reach/River: Red River

Use: Irrigation **Acres**: 5 [10 in '99] **Intake location**: Hwy. 210, St. Adolphe

Description: raspberries (5 acres) [asparagus, **Quantity/Rate/Time of Year**: 1"/week, May

tomatoes and peppers in '99] and June

May 7, 1998—Interviewee said he and his wife use water from the Red River to irrigate approximately 5 acres of raspberries. Next year, they will be adding 5 acres of asparagus, tomatoes, and peppers. Interviewee said he pumps water from the river near Hwy. 210 in St. Adolphe, Manitoba. He estimates that, on average, he uses approximately 1 inch of water a week in May and June. He describes current water *quantity* as good, but is not satisfied with the water *quality*. He says that the water in the river is so turbid that he must use a gun sprinkler system, but would prefer to use a drip system. Mr. Alty indicated that if salinity of the water were to increase, it would cause extensive damage to his fruit crop. Currently, he earns approximately \$45,000 a year from his raspberries $(3,000 \text{ lbs. per acre} \times \$1.50 \text{ per lb.} \times 10 \text{ acres})$. If he were forced to farm

another, less sensitive, crop, such as wheat, he would earn only about \$1,800 a year (40 bushels an acre \times \$4.50 per bushel \times 10 acres), which result in a loss of \$43,200. Mr. Alty is unaware of any other source of water. [syh]

Interview#: 15 **Reach/River**: Sheyenne River

Use: Irrigation **Acres:** 500 **Intake location:** south and east of town of Sheldon

Description: corn 65%, potatoes 20%, soybeans 15%; livestock **Quantity/Rate/Time of Year**: 17 inches over 500 acres during the growing season (peak use in July

and Aug.)

May 8, 1998—Interviewee uses water from the Sheyenne River to irrigate approximately 500 acres of land (portions of which are rented from Byron Stoffel and Elaine Kerian) and to care for a small herd of cattle. His crops consist of approximately 65 percent corn, 20 percent potatoes, and 15 percent soybeans. Water is taken from two diversion points to the south and east of the town of Sheldon, ND. According to Mr. Pfingsten, in a typical irrigation season, he pumps approximately 17 inches of water over 500 acres of land, with peak water use in July and August. He considers current water quality good; it is soft and rich in nutrients. Interviewee said that salinity can cause problems if the concentration were too high over the long term; however, he did not believe that salinity would be an issue for watering the cattle. It the concentration of salts in the water became too high, interviewee indicated he would need to stop irrigating before it caused damage to his land and rendered it useless. He also said that in the areas of his land where the soil is sandy, salts would build up even faster than in other areas. Furthermore, interviewee believes his crops would not survive without irrigation. He said that because his land is so close to the river, water from wells is unavailable or difficult to find. He uses well water for additional acres of crops situated farther from the river, but he has been unable to drill a well close to the river. Although interviewee was unable to quantify costs of damages and/or solutions pertaining to crop loss, he was able to provide a cost related to the potential impacts of pumping water from Devils Lake into the Sheyenne. With foresight, he had installed a new pumping station, at a cost of \$50,000, that allows the pump to handle fluctuating water levels. According to interviewee, if water is to be pumped into the river, the levels will change enough that other users of the river will need to install pump stations, too. Another major concern for interviewee is the eroding of the river banks, because his pumping station will need to be moved if the bank eroded from the increase in the river water's quantity and velocity. Interviewee is more concerned about the erosion of river banks, fluctuations in water levels, and the costs associated with both than he is about changes in water quality. [isf]

Interview#: 16 **Reach/River**: Sheyenne River

Use: Irrigation **Acres**: 140 **Intake location**: Lisbon, ND

Description: alfalfa **Quantity/Rate/Time of Year:** avg. 1 to 2 acre-

feet during the growing season

May 11, 1998—Interviewee uses water from the Sheyenne River in Lisbon to irrigate approximately 140 acres of alfalfa. He said that on average, he uses about 1 to 2 acre-feet of water per year; however, the amount varies each year depending on rainfall. Interviewee described the current water quality as "just fine." He has two main concerns about the proposed pumping of water from

Devils Lake into the Sheyenne River. The first is that if the salinity of the water increases enough, it could cause soil damage and destroy interviewee's alfalfa crops. Interviewee said that the riverbottom soil on the majority of his 140 acres doesn't allow salt to percolate through. If the soil were sandier, the salt would flush out. Interviewee knows of no other alternatives for water in his area; he has already tried unsuccessfully to drill a well. If he had to cease irrigating his crops, not only would the crops suffer, but his \$60,000 investment in his irrigation system would be lost. Interviewee is also concerned that pumping from Devils Lake would increase the Sheyenne's potential for flooding. He explained that if the water level gets too high in Bald Hill Reservoir in Valley City, the reservoir is opened and water subsequently floods his land. Interviewee said that he had lost approximately 60 acres of crops one year when water was released from the reservoir due to high rainfall. He believes pumping water from Devils Lake would compound that problem. It costs interviewee \$100 an acre to reseed after a flood. [jsf]

May 11, 1998—Interviewee uses water from the Red River to irrigate between 400 and 600 acres of varying crops, including potatoes and sugar beets. The amount of acres and types of crops irrigated varies year to year. Interviewee's land is located approximately 5 miles south of Grand Forks and water is taken from the river near the area where a highline pole crosses the Red River. The amount of water he uses from the Red River depends on the seasonal rainfall; on average he estimates that he uses 2 to 4 inches over 600 acres per year. Interviewee describes current water quality as very good. He said he has no concerns about changes in water quality affecting his crops, including increased salinity and hardness. He also said that he doesn't believe there would be an increased risk of flooding since the water would likely be pumped to the river at a moderate rate. [jsf]

Interview#: 18 Reach/River: Red River

Use: Irrigation **Acres**: 45 **Intake location**: 2.5 north of the Winnipeg

perimeter highway

Description: Cemetery lands **Quantity/Rate/Time of Year**: 2 million gallons a

year from May through Sept.

May 12, 1998—Interviewee said he uses water from the Red River to irrigate approximately 45 acres of cemetery land. The cemetery's water intake location is approximately $2\frac{1}{2}$ miles north of the perimeter highway in Winnipeg. Interviewee said he is currently satisfied with the quality of the water he is getting from the Red River. He believes that an increase in nutrients in the water would have a major affect on his lands. He said that a well would not work because it would have to be too large; he doesn't know of any other alternative to the river. Interviewee was unable to quantify specific costs of damages and/or solutions. [syh]

Interview#: 19 Reach/River: Red River

Use: Irrigation **Acres**: 15 **Intake location**: 2 miles south of floodway

Description: peppers, tomatoes, cabbage, **Quantity/Rate/Time of Year**: 6 acres at 300

celery, peas, and beans gallons per minute

May 12, 1998—Interviewee indicated he uses water from the Red River to irrigate approximately 15 acres of crops including peppers, tomatoes, cabbage, celery, peas, and beans. Interviewee irrigates his crops from the end of May through the beginning of August. He does not know the quantity of water he uses throughout the season; however, information from Agassiz Irrigation says it is "6 acres @ 300 gpm." Interviewee is currently satisfied with the water quality of the Red River. He says the effects of water quality changes would depend of the types of contamination; he indicated that he would only be speculating if he tried to determine what the effects would be. In terms of solutions or responses to a change in water quality, interviewee said that wells are a possibility but that the groundwater might be salty and not good for crops. He said that it would be a big loss to lose the river as a source of water. Interviewee was unable to quantify costs of damages and/or solutions. [syh]

Interview#: 20 Reach/River: Red River

Use: Irrigation **Acres**: 30 **Intake location**: 3042 Mary's Road, south end of

city of St. Germain

Description: cabbage, cauliflower, **Quantity/Rate/Time of Year**: 250 gpm; 1 inch

peppers, tomatoes (no root crops) per watering

May 12, 1998—The farm uses water from the Red River to irrigate approximately 30 acres of vegetable crops (no root crops), including cabbage, cauliflower, peppers, and tomatoes. According to interviewee, all crops are irrigated in the spring, and irrigation continues on a as-needed basis from June through August at 250 gpm, with 1 inch of water per watering. Interviewee is currently satisfied with the water quality of the Red River. He believes increased salinity would be disastrous, costing him approximately \$150,000 a year. He also indicated that wells would be very expensive and might not be allowed in a residential area. Interviewee was unable to quantify the costs of possible solutions. [syh]

Interview#: 21 Reach/River: Red River

Use: Irrigation **Acres**: 15 **Intake location**: Drury Avenue, just north of

Winnipeg

Description: tomatoes, cauliflower, **Quantity/Rate/Time of Year**: 6 inches to one foot

cabbage (no root crops) over 15 acres per year

May 12, 1998—Interviewee uses water from the Red River to irrigate approximately 15 acres of vegetable crops (no root crops) including tomatoes, cauliflower, and cabbage. He estimated his water use at approximately 6 inches to 1 foot over 15 acres per year. He described current water quality as good, and said that many, many years ago the quality was not very good, but he didn't

know why. Interviewee said a pH level of 7.5 is too high; he wasn't sure what numbers were too high for other parameters. If water quality changed and adversely affect his crops, interviewee said he would lose his livelihood but he was unable to quantify that with a dollar amount. As for alternatives to river water, he said the costs of those solutions would be "astronomical" and that wells in Manitoba wouldn't do the job because the water is too cold and hard. [syh]

Interview#: 22 Reach/River: Red River

Use: Irrigation **Acres**: 280 **Intake location**: 8–9 miles south of Grand Forks,

in rural Thompson

Description: potatoes, beets, and **Quantity/Rate/Time of Year**: 5 to 8 inches over

sometimes beans 280 acres

May 15, 1998—Interviewee uses water from the Red River to irrigate approximately 280 acres of potatoes, beets, and sometimes beans. He said he uses about 5 to 8 inches of water over 280 acres per year (but last year he irrigated only 80 acres). He describes current water quality as very good—better than well water because it doesn't corrode irrigation systems and is not so high in hard minerals. Interviewee doesn't believe that pumping from Devils Lake would affect the quality of river water because any contaminants from Devils Lake would be diluted by the time they reached his land. He believes Devils Lake will overflow eventually anyway, and it would be better to have controlled pumping. [jsf]

Interview#: 23 Reach/River: Sheyenne River

Use: Irrigation **Acres:** 6 **Intake location:** 2 miles south of Valley City

Description: yard, trees **Quantity/Rate/Time of Year**: 1 inch over 6 acres

during the summer

May 22, 1998—Interviewee uses water from the Sheyenne River to irrigate approximately 6 acres of lawn and trees. He estimates he uses 1 inch of water over 6 acres during the summer. He is currently satisfied with the water quality of the river and foresees no effects from a change in water quality. [txc]

Interview#: 24 **Reach/River**: Sheyenne River

Use: Irrigation **Acres:** 100 **Intake location:** 500 feet from river, in Tolna, ND

Description: land nursery—seedling **Quantity/Rate/Time of Year**: half an acre per

pumping year with 1 inch of water

May 22, 1998—Interviewee uses water from the Sheyenne River for the irrigation of seedlings. He farms approximately 100 acres of trees, and for the past few years, has needed to irrigate only the new seedlings (approximately half an acre) with 1 inch of water per year. Interviewee is currently

satisfied with the water quality of the river and foresees no effects on his operations or crops if the water quality changes. [txc]

Interview#: 25 Reach/River: Red River

Use: Irrigation Acres: 80 Intake location: Akin Township, Polk County

(section 7, 20 miles north of Grand Forks)

Description: sugar beets and potatoes **Quantity/Rate/Time of Year**: 6 inches over 80

acres (in a dry year) during July

May 22, 1998—Interviewee uses water from the Red River to irrigate approximately 80 acres of sugar beets, potatoes, and sometimes wheat. He said he uses approximately 6 inches of water over 80 acres in a dry year, mainly in July. Interviewee is satisfied with the water quality of the river and believes that changes in salinity, hardness, or dissolved solids would not affect his crops. [txc]

Interview#: 26 Reach/River: Red River

Use: Irrigation **Acres**: 14 **Intake location**: edge of Walley Township

Description: row crops: potatoes and **Quantity/Rate/Time of Year:** 12 inches over 14

beets; "truck gardening" acres during summer

May 22, 1998—Interviewee uses water from the Red River to irrigate row crops, including potatoes and beets for "truck gardening." His farm is located on the edge of Walley Township. He said he uses approximately 12 inches of water over 14 acres during the summer. He said he is currently satisfied with the water quality. Interviewee suggested that an increase in salinity might affect crops, but he wasn't sure, and was unable to quantify costs of damages and/or solutions. [txc]

Interview#: 27 **Reach/River**: Sheyenne River

Use: Irrigation **Acres:** 1 acre **Intake location:** south of West Fargo

Description: Garden and lawn watering **Quantity/Rate/Time of Year**: unknown quantity;

summer

May 26, 1998—Interviewee uses an unknown quantity of water from the Sheyenne River (south of West Fargo) to water approximately 1 acre of lawn and garden in the summer. Interviewee said that she is currently satisfied with the river's water quality. She said that if the water quality were to degrade, she would need to consider using the rural water source. [txc]

Interview#: 28 Reach/River: Sheyenne River

Use: Irrigation **Acres**: 60-100 **Intake location**: 9 miles east of Lisbon

Description: corn and beans **Quantity/Rate/Time of Year**: 1 inch over 60 to

100 acres during the growing season

May 26, 1998—Interviewee uses water from the Sheyenne River to irrigate between 60 and 100 acres of corn and beans. During the growing season, he uses approximately 1 inch of water per 60 to 100 acres of crops. Interviewee said that he is currently satisfied with the river's water quality, but would expect problems for his crops if the quality changed. He said that it would cost him money to stop irrigating because there is less crop yield from nonirrigated land (110 to 140 bushels per acre irrigated vs. 20 to 30 bushels per acre not irrigated). At \$2 per bushel, there would be an estimated loss of \$15,200 for 80 acres. [txc]

Interview#: 29 Reach/River: Sheyenne River

Use: Irrigation **Acres**: 35 **Intake location**: Lee Township

Description: strawberries **Quantity/Rate/Time of Year**: 1 inch over 35

acres in the summer

May 27, 1998—Interviewee uses water from the Sheyenne River in Lee Township to irrigate approximately 35 acres of strawberry crops. He uses approximately 1 inch of water over 35 acres per summer. He said he is currently satisfied with the water quality and does not anticipate any adverse effect on his strawberry crop if the water quality changes. [txc]

Interview#: 30 (has 2 permits) Reach/River: Red River

Use: Irrigation **Acres:** 200 **Intake location:** 15 miles south of Grand Forks

Description: beets, beans, and potatoes **Quantity/Rate/Time of Year**: 3.5 inches over 200

acres per year

May 27, 1998—Interviewee uses water from the Red River to irrigate approximately 200 acres of beets, beans, and potatoes. He said he uses approximately 3.5 inches of water over 200 acres per year. He is currently satisfied with the water quality of the river and does not foresee any impacts to his crops from a possible change in water quality. [txc]

Interview#: 31 Reach/River: Red River

Use: Irrigation **Acres:** 77 **Intake location:** on river bank in the parish of

Kildonan

Description: golf course **Quantity/Rate/Time of Year**: 1 inch per week on

fairways and 2 inches per week on greens, May

through mid-September

May 27, 1998—Interviewee is the superintendent of a golf course. The city uses water from the Red River to irrigate approximately 80 percent of 96.4 acres (77 acres) of fairways and greens of the 18-hole course. According to interviewee, water is pumped from the river banks beginning the first week of May and continuing through the second week of September. He said the city uses approximately 1 inch of water per week on the fairways and 2 inches per week on the greens. Interviewee is currently satisfied with the quality of water he uses on the course. He believes an increase in salinity of water would wipe out the greens because salt is toxic to them. He said the groundwater is too saline and to tap into city water would cost \$30,000 a year (Canadian) for an 18-hole golf course. He also said that if city water were to become scarce, recreational users would be the first to forfeit its use. According to interviewee, to replace a damaged green costs \$25,000 to \$30,000 (Canadian); he would expect losses in revenue to average \$600,000 a year (Canadian). [syh]

Interview#: 32 Reach/River: Red River

Use: Irrigation **Acres**: 26 **Intake location**: on river bank in the parish of St. Vital

Description: golf course **Quantity/Rate/Time of Year**: 1 inch per week on

fairways and 2 inches per week on greens, May to mid-

September

May 27, 1998—Interviewee indicates the city uses water from the Red River to irrigate approximately 80 percent of 32.5 acres (26 acres) of fairways and greens of the 9-hole, par-3 golf course. According to interviewee, water is pumped from the river banks beginning the first week of May and continuing through the second week of September. He said that the city uses approximately 1 inch of water per week on the fairways and 2 inches per week on the greens. Interviewee is currently satisfied with the quality of water he uses on the course. He believes an increase in salinity of water would wipe out the greens because salt is toxic to them. He said the groundwater is too saline and to tap into city water would cost \$10,000 to \$12,000 a year (Canadian) for 9-hole course. He also said that if city water were to become scarce, recreational users would be the first to forfeit its use. According to interviewee, to replace a damaged green costs \$25,000 to \$30,000 (Canadian); he would expect losses in revenue to average \$300,000 a year (Canadian). [syh]

Interview#: 33 Reach/River: Sheyenne River

Use: Fish and wildlife **Acres**: N/A **Intake location**: Bald Hill National Fish

Hatchery (NFH)

Description: Fish hatchery (U.S. Fish and **Quantity/Rate/Time of Year**: avg: 170 (acre-

Wildlife Service; FWS)

May 28, 1998—According to interviewee water taken from the Sheyenne River at Bald Hill NFH is used in fish hatcheries. The FWS tracks water use by facility, not permit number. Interviewee said that an average of 170 acre-feet of water is taken from the river at the Bald Hill facility in a year and described the current water quality as "okay." There are no specific water-quality requirements for these fish hatcheries, but interviewee indicated that water quality parameters can affect stream fish directly through the water or indirectly through effects on food production. She made reference to a book that she thought might have specific water-quality requirements for fish. According to interviewee, there are no other water sources that the FWS could reasonably tap, and the costs in loss of fish and forgone recreation opportunities could cost several million dollars. [jsf]

Interview#: 34 Reach/River: Sheyenne River

Use: Recreation **Acres**: N/A **Intake location**: Valley City National Fish

Hatchery (NFH)

Description: Fish hatchery (U.S. Fish and **Quantity/Rate/Time of Year**: avg. 1,000 acre-

Wildlife Service; FWS)

feet

May 28, 1998—According to interviewee water taken from the Sheyenne River at Valley City NFH under three permit numbers is used in fish hatcheries. The FWS tracks water use by facility, not permit number. Interviewee said that an average of 1,000 acre-feet of water is taken from the river at the Valley City facility in a year, and described the current water quality as "okay." There are no specific water-quality requirements for these fish hatcheries, but interviewee indicated that water quality parameters can affect stream fish directly through the water or indirectly through effects on food production. She made reference to a book that she thought might have specific water-quality requirements for fish. According to interviewee, there are no other water sources that the FWS could reasonably tap, and the costs in loss of fish and forgone recreation opportunities could cost several million dollars. [jsf]

Interview#: 35 Reach/River: Red River

Use: Irrigation **Acres**: 110 **Intake location**: East Grand Forks

Description: Golf course **Quantity/Rate/Time of Year**: during a dry year,

12 million gallons per season

May 29, 1998—Interviewee indicated that the course uses water from the Red River to irrigate approximately 110 acres of lawn on the golf course. In a dry year, the facility uses approximately 12 million gallons. Interviewee describes the current water quality as acceptable. He said an increase in salinity would be devastating because salt would turn the soil alkaline. He said that the association has no other source of water, and that if water quality were to change, the association would have to consider building a well or using overspillage from the sugar-beet factory. Interviewee did not quantify costs of damages and/or solutions. [txc]

Interview#: 36 Reach/River: Red River

Use: Irrigation **Acres**: 300 **Intake location**: 6 miles south of Drayton

Description: sugar beets, potatoes, and beans (on rotation) **Quantity/Rate/Time of Year**: in a dry year, 8 inches over 300 acres; in a wet year, 1 inch

May 29, 1998—Interviewee uses water from the Red River to irrigate 300 acres of sugar beets, potatoes, and beans (rotational crops). His land needs approximately 8 inches of water over 300 acres in a dry year and about 1 inch in a wet year. He describes current water quality as acceptable. He said that if salinity in the water quality were to increase, he wouldn't be able to irrigate any longer, and added that the clay-based soil doesn't need anymore salt. Interviewee is also concerned about flooding and subsequent draining of the land. He believes an increase in water in the Red River would cause more problems in terms of flooding and draining. He is also concerned that an increase in resorts and fishing activities could affect water quality. If changes in water quality or quantity were to occur, interviewee said there would be a lower yield of crops, even if he kept irrigating. He was unable to quantify the costs of damages and/or solutions associated with these changes. [txc]

Interview#: 37 Reach/River: Red River

Use: Irrigation **Acres**: 140 **Intake location**: different locations

throughout Grand Forks

Description: Lawn, trees, flowers (Grand **Quantity/Rate/Time of Year**: dry = 4" over

Forks Park District) 140 acres; wet= 1"/140 acres

May 29, 1998—Interviewee said that the Grand Forks Park District uses water from the Red River to irrigate approximately 140 acres of lawn, trees, and flowers scattered throughout the city. In a dry year, he said the Park District uses 4 inches of water over the 140 total acres; in a wet year, about an inch. He said that he is currently satisfied with the water quality of the river, but that if it were to change, there would be no ill effects to the Park District, which would use city water instead. [txc]

Appendix F

Information Summaries: Industrial Users

Interview #: 1

Industry Type: Quarry

Location: 3 miles NW of Sheyenne, ND

Questions to ask Industries

You currently hold a permit for river water use. Do you use the river as a source water? Yes. They currently use the Sheyenne River.

Do you use the river for drinking water purposes?

No

What process or processes do you use the water for?

Wash sand and gravel.

What is the average flow rate that you use the water? What is the frequency, weekly and seasonally? Normal workday or 24 hours?

They use the water seasonally, from April through October. They draw water 12 hr/day, 60 hr/week, for a total of approximately 65 million gallons per year.

Do you treat the water for a process and/or for drinking water? If so, how? Is there a required effluent quality?

They do not treat the water. After use it goes to a settling pond where it is allowed to infiltrate to the ground.

Do you have an alternate water source if river water is not suitable or not available? No

Do you anticipate any changes in the rate of water usage?

Nο

What is the cost of treatment operations?

N/A

What is the capacity of the treatment system? (Flow capacity and hardness capacity) $\rm N\!/\!A$

What chemicals are necessary for treatment? What is the chemical used? How much of each chemical do you use? What is the cost of using each chemical? No chemicals are used.

Do you regularly analyze for water quality parameters? What are typical water quality parameters for raw water and treated water? No, they do not analyze the water.

Comments: The interviewee is the area manager for the quarry. Interviewee expressed general concern that an increase in water quantity in the river would cause the riverbanks to erode further and the river to jump the banks more often. He explained that over the years, the river has been filling in with silt, making it easier for the river to jump its banks.

Industry Type: Construction **Location:** Valley City, ND

Questions to ask Industries

You currently hold a permit for river water use. Do you use the river as a source water?

They do not currently use the river. They maintain a permit to use the Sheyenne River in case they want to use it in the future.

Do you use the river for drinking water purposes?

No

What process or processes do you use the water for?

In the future, they may use it to wash rock material.

What is the average flow rate that you use the water? What is the frequency, weekly and seasonally? Normal workday or 24 hours?

Don't use any water now.

Do you treat the water for a process and/or for drinking water? If so, how? Is there a required effluent quality?

No

Do you have an alternate water source if river water is not suitable or not available?

Do you anticipate any changes in the rate of water usage?

They may use the river in 5 or 10 years.

What is the cost of treatment operations?

N/A

What is the capacity of the treatment system? (Flow capacity and hardness capacity)

N/A

What chemicals are necessary for treatment? What is the chemical used? How much of each chemical do you use? What is the cost of using each chemical?

No chemicals are used.

Do you regularly analyze for water quality parameters? What are typical water quality parameters for raw water and treated water? No, they do not analyze the water.

Comments: The interviewee is the president of the company. They don't currently use the river, but in 5-10 years they may use it to wash rock and other materials.

Industry Type: Ski Area **Location:** Ft. Ransom, ND

Questions to ask Industries

You currently hold a permit for river water use. Do you use the river as a source water? Yes. They currently use the Sheyenne River.

Do you use the river for drinking water purposes?

No

What process or processes do you use the water for?

Snow making.

What is the average flow rate that you use the water? What is the frequency, weekly and seasonally? Normal workday or 24 hours?

They use the river water during the winter. The frequency depends upon how much snow they have. Over the past 3 years they have averaged 2.3 million gallons per year.

Do you treat the water for a process and/or for drinking water? If so, how? Is there a required effluent quality?

No

Do you have an alternate water source if river water is not suitable or not available? $_{\mathrm{No}}$

Do you anticipate any changes in the rate of water usage?

Rate of water usage depends on the amount of snow, so it varies every year.

What is the cost of treatment operations?

N/A

What is the capacity of the treatment system? (Flow capacity and hardness capacity)

What chemicals are necessary for treatment? What is the chemical used? How much of each chemical do you use? What is the cost of using each chemical? No chemicals are used.

Do you regularly analyze for water quality parameters? What are typical water quality parameters for raw water and treated water? No, they do not analyze the water.

Comments: The interviewee is the manager of the ski area. He doesn't think this will be a problem. He says that increased solids may even help his snow making capabilities. They don't currently have any problems with hardness/scaling and don't anticipate any if the hardness increased.

Industry Type: Construction **Location:** Lisbon, ND

Questions to ask Industries

You currently hold a permit for river water use. Do you use the river as a source water? Yes. They currently use the Sheyenne River.

Do you use the river for drinking water purposes?

No

What process or processes do you use the water for?

Wash aggregate.

What is the average flow rate that you use the water? What is the frequency, weekly and seasonally? Normal workday or 24 hours?

They use the water seasonally, from April through October. They typically use 200,000 gallons to 300,000 gallons per day. In 1997 they used 6,305,000 gallons.

Do you treat the water for a process and/or for drinking water? If so, how? Is there a required effluent quality?

They don't treat the water. After use it goes to 2 lagoons for settling and then discharged to river.

Do you have an alternate water source if river water is not suitable or not available?

They don't have another source. They do use groundwater at 57,000 gallons per year for other purposes. If the river is high they just don't use it.

Do you anticipate any changes in the rate of water usage?

No

What is the cost of treatment operations?

N/A

What is the capacity of the treatment system? (Flow capacity and hardness capacity) $\rm N\!/\!A$

What chemicals are necessary for treatment? What is the chemical used? How much of each chemical do you use? What is the cost of using each chemical?

No chemicals are used.

Do you regularly analyze for water quality parameters? What are typical water quality parameters for raw water and treated water? No, they do not analyze the water.

Comments: The interviewee is an office employee for the company. They feel this is of no concern to their operation.

Industry Type: Municipality

Location: West Fargo, North Dakota

Questions to ask Industries

You currently hold a permit for river water use. Do you use the river as a source water? See comments below.

Do you use the river for drinking water purposes?

What process or processes do you use the water for?

What is the average flow rate that you use the water? What is the frequency, weekly and seasonally? Normal workday or 24 hours?

Do you treat the water for a process and/or for drinking water? If so, how? Is there a required effluent quality?

Do you have an alternate water source if river water is not suitable or not available?

Do you anticipate any changes in the rate of water usage?

What is the cost of treatment operations?

What is the capacity of the treatment system? (Flow capacity and hardness capacity)

What chemicals are necessary for treatment? What is the chemical used? How much of each chemical do you use? What is the cost of using each chemical?

Do you regularly analyze for water quality parameters? What are typical water quality parameters for raw water and treated water?

Comments: The interviewee is the water superintendent. The municipality does not use river water for any purposes. They have kept all past permits as a contingency, in case they have problems with their groundwater and would require river water. They have no plans to use river water unless something unforeseen happens. The interviewee was unaware that they had an industrial use permit, and stated they do not use the river water for any industrial purpose.

Industry Type: Sugar Beet Processing

Location: Winnipeg, Manitoba

Questions to ask Industries

You currently hold a permit for river water use. Do you use the river as a source water? See comments below.

Do you use the river for drinking water purposes?

What process or processes do you use the water for?

What is the average flow rate that you use the water? What is the frequency, weekly and seasonally? Normal workday or 24 hours?

Do you treat the water for a process and/or for drinking water? If so, how? Is there a required effluent quality?

Do you have an alternate water source if river water is not suitable or not available?

Do you anticipate any changes in the rate of water usage?

What is the cost of treatment operations?

What is the capacity of the treatment system? (Flow capacity and hardness capacity)

What chemicals are necessary for treatment? What is the chemical used? How much of each chemical do you use? What is the cost of using each chemical?

Do you regularly analyze for water quality parameters? What are typical water quality parameters for raw water and treated water?

Comments: The phone number listed above was disconnected and I was forwarded to another number, which is their Vancouver, BC plant. The interviewee said that the Winnipeg plant has been closed and is not being operated. The only activity there is selling equipment. So they are not using river water anymore. They have no plans to use the site in the future and may sell the land. The interviewee is an operations assistant in the engineering department of the Vancouver plant.

Location: Winnipeg, Manitoba **Industry Type:** Construction

Questions to ask Industries

You currently hold a permit for river water use. Do you use the river as a source water? No. See comments below.

Do you use the river for drinking water purposes?

No. They currently do not use Red River for any purpose at their facility.

What process or processes do you use the water for?

None.

What is the average flow rate that you use the water? What is the frequency, weekly and seasonally? Normal workday or 24 hours?

N/A

Do you treat the water for a process and/or for drinking water? If so, how? Is there a required effluent quality?

N/A

Do you have an alternate water source if river water is not suitable or not available? They use well water for drinking and all other purposes at the facility.

Do you anticipate any changes in the rate of water usage?

N/Δ

What is the cost of treatment operations?

N/A

What is the capacity of the treatment system? (Flow capacity and hardness capacity) $\rm N\!/\!A$

What chemicals are necessary for treatment? What is the chemical used? How much of each chemical do you use? What is the cost of using each chemical? N/A

Do you regularly analyze for water quality parameters? What are typical water quality parameters for raw water and treated water? N/A

Comments: The interviewee is the operation manager for the company. The permit is old and the interviewee has never seen the permit nor did he know the permit number or its location at their facility. The facility used to be located on the Red River but moved 5 miles away from the Red River in 1979. The old facility may have used Red River water for ready mix concrete and concrete truck washing.

Industry Type: Municipality **Location:** Winnipeg, Manitoba

Questions to ask Industries

You currently hold a permit for river water use. Do you use the river as a source water? See comments below.

Do you use the river for drinking water purposes?

What process or processes do you use the water for?

What is the average flow rate that you use the water? What is the frequency, weekly and seasonally? Normal workday or 24 hours?

Do you treat the water for a process and/or for drinking water? If so, how? Is there a required effluent quality?

Do you have an alternate water source if river water is not suitable or not available?

Do you anticipate any changes in the rate of water usage?

What is the cost of treatment operations?

What is the capacity of the treatment system? (Flow capacity and hardness capacity)

What chemicals are necessary for treatment? What is the chemical used? How much of each chemical do you use? What is the cost of using each chemical?

Do you regularly analyze for water quality parameters? What are typical water quality parameters for raw water and treated water?

Comments: In the past, the municipality operated a coal fired generator station that used the river water. They haven't operated the station in a long time and have no plans to operate in the future.

Industry Type: Sugar Beet Processing

Location: Drayton, ND

Questions to ask Industries

You currently hold a permit for river water use. Do you use the river as a source water?

Yes. They currently use the Red River.

Do you use the river for drinking water purposes?

No

What process or processes do you use the water for?

Cooling water and to transport beets into the factory, and make-up water for the process.

What is the average flow rate that you use the water? What is the frequency, weekly and seasonally? Normal workday or 24 hours?

This year, no water was taken from the river. In the past, less than 100 million gallons per year is taken, once a year to fill a storage pond. (Data obtained from the North Dakota State Water Commission shows in previous years they have taken from the river in September, October, and November.)

Do you treat the water for a process and/or for drinking water? If so, how? Is there a required effluent quality?

Water is included with beet water if they need extra water. This water is softened, filtered through a diatomaceous earth filter, and then boiled.

Do you have an alternate water source if river water is not suitable or not available?

They preferentially use beet water, but use the river water if they need extra water.

Do you anticipate any changes in the rate of water usage?

They want to decrease river water use.

What is the cost of treatment operations?

Treatment is integrated with the process so they won't say based upon trade secret.

What is the capacity of the treatment system? (Flow capacity and hardness capacity)

5 MGD maximum capacity of the process. Typically 1.5 MGD.

What chemicals are necessary for treatment? What is the chemical used? How much of each chemical do you use? What is the cost of using each chemical?

Lime for softening, a FDA flocculant polymer is used. Lime is used as part of the sugar extraction process.

Do you regularly analyze for water quality parameters? What are typical water quality parameters for raw water and treated water? No, only measure discharge water.

Comments: The interviewee is responsible for water use reporting and he completes the water permit applications for the facility. They have 4 plants along the Red River, the interviewee thought that the Drayton plant is the only one currently using the river. The East Grand Forks plant was contacted and engineering department staff confirmed that only the Drayton plant uses water from the Red River. The Drayton plant holds a Minnesota permit and a North Dakota permit for one intake. The Red River is a border river so they report their water use to both states. The interviewee said that typically less than 100 million gallons is pumped during September. Interviewee considers current water quality to be good, but foresees problems if water quality were to change; he believes an increase in hardness and dissolved solids

would affect operations and that the factory would need to consider alternatives to river water. If water quality were to change on a short-term basis, costs to the company would vary depending on the time of the year. For example, if quality changed in September, modifications would need to be taken so as not to take water from the river. If the quality changed on a long-term basis, the company would need to find a new water source or make modifications in the factory setup. Interviewee indicated that expenses associated modifying the operations could cost as much as several million dollars, but he was unable to quantify the specific costs of damages and/or solutions.

Industry Type: Hydropower Plant **Location:** Winnipeg, Manitoba

Questions to ask Industries

You currently hold a permit for river water use. Do you use the river as a source water? Yes. They currently use the Red River.

Do you use the river for drinking water purposes?

No.

What process or processes do you use the water for?

Water is pumped from the Red River and used for 3 different operations:

- 1. 99% of the water is cooling water for condensers units.
- 2. < 1% is used to transport fly ash (by product from coal burning) to an ash lagoon.
- 3. < 1% is treated for hardness and used for boiler feed pump cooling and occasionally boiler makeup.

What is the average flow rate that you use the water? What is the frequency, weekly and seasonally? Normal workday or 24 hours?

Water is pumped continuously from the Red River by two single stage, mixed flow impeller pumps. Each pump, when running at full throttle, has a maximum capacity of 103 MGD. However, they have historically never pumped at max capacity and do not anticipate that they will in the future. Average flows are highly variable. Average flow rates were not provided.

Do you treat the water for a process and/or for drinking water? If so, how? Is there a required effluent quality?

Yes, they treat a small portion of the water pumped from the Red River. Less than 1% of the total water pumped from the Red River is treated for hardness and mineral removal by ion exchange and used for boiler feed pump cooling and occasionally boiler makeup. Additionally, they use well water for drinking, which is chlorinated, and not water from the Red River.

Condenser cooling water is discharged untreated to Cooks Creek. Decant water from the ash lagoon and water used for boiler feed pump cooling is discharged untreated to the Red River. They have not needed to treat the water to date, as the effluent quality is in compliance with limits set forth in their Provincial Environmental Act License.

Do you have an alternate water source if river water is not suitable or not available?

They have a well in place. They use well water for drinking at the facility, but they have never used it in their process as a substitute for Red River water.

Do you anticipate any changes in the rate of water usage?

No.

What is the cost of treatment operations?

No information provided.

What is the capacity of the treatment system? (Flow capacity and hardness capacity) No information provided.

What chemicals are necessary for treatment? What is the chemical used? How much of each chemical do you use? What is the cost of using each chemical?

No information provided.

Do you regularly analyze for water quality parameters? What are typical water quality parameters for raw water and treated water?

No information provided.

Comments: The interviewee is the senior environmental officer at the facility. Interviewee has stated that Manitoba Hydro has decided not to provide any additional information. When first contacted, the interviewee said they would be willing to provide chemical cost estimates, water quality data, and average flow rates. However, they have decided not to provide this information. He did say that any significant increase in the concentration of sulfates, chlorides, hardness, and suspended solids in the river could negatively affect the station components and operating systems. In addition, any significant increase in the concentration of suspended solids, copper, nickel, zinc, and pH in the river could make it more difficult to comply with liquid effluent limits established in the station's Provincial Environment Act License. According to interviewee, additional debris in the water could cause problems. Currently the station has approximately 10,000 1-inch tubes, screens, and fish fences to keep debris and wildlife out. Interviewee also said that the salinity could affect operations. He said there are no alternatives for the cooling process; too much water is needed. He said that a deep well could be used for the 1 percent of water that is treated. Interviewee was unable to quantify costs of damages and/or solutions.

Industry Type: Paper Mill **Location:** Winnipeg, Manitoba

Questions to ask Industries

You currently hold a permit for river water use. Do you use the river as a source water? Yes, they currently use the Red River.

Do you use the river for drinking water purposes?

No

What process or processes do you use the water for?

Transport of paper fiber, paper processing, and washing machinery. The process requires 99% water to 1% paper fiber.

What is the average flow rate that you use the water? What is the frequency, weekly and seasonally? Normal workday or 24 hours?

2 MGD, but they recycle all but 50,000 GPD. So they take 50,000 GPD from the Red River.

Do you treat the water for a process and/or for drinking water? If so, how? Is there a required effluent quality?

Filter out fish and use successively finer filters to remove sand, silt, and suspended solids. Silt is a serious problem for them.

Do you have an alternate water source if river water is not suitable or not available? City water, but it is expensive.

Do you anticipate any changes in the rate of water usage?

They are considering adding one more milling machine which would increase the river water usage to 75,000 GPD. They do not currently use river water for boilers, but they may in the future.

What is the cost of treatment operations?

Ali did not specify the cost of treatment. He said the chemical costs are low.

What is the capacity of the treatment system? (Flow capacity and hardness capacity)

The system is currently near capacity. If they expand, as mentioned above, the system would be at maximum capacity.

What chemicals are necessary for treatment? What is the chemical used? How much of each chemical do you use? What is the cost of using each chemical?

Polymers are used, but cost and quantity were not given.

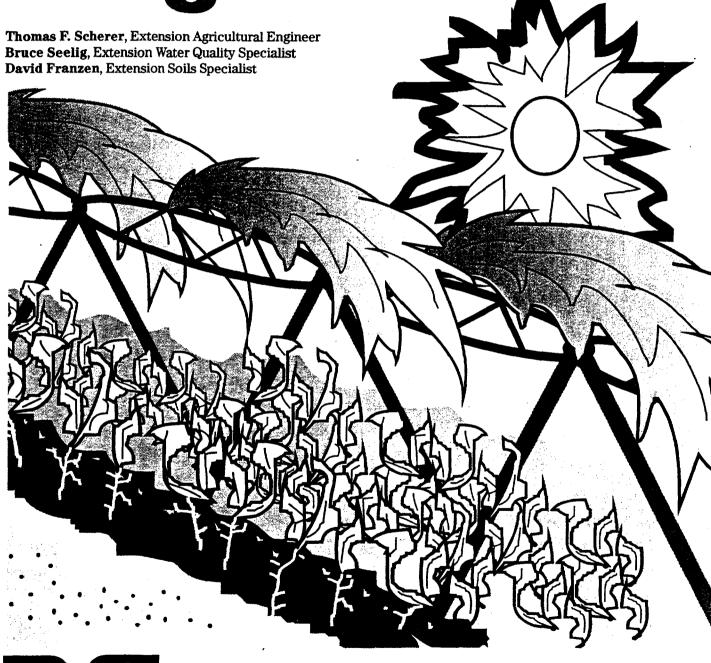
Do you regularly analyze for water quality parameters? What are typical water quality parameters for raw water and treated water? No information was given.

Comments: The interviewee is a water chemist. Interviewee indicated there should be no effect to the chemical process of paper-making if the water quality were to change because they do not make white paper. If they were to make white paper, which would require installation of a new machine, they would require high quality water. The interviewee was unable to state what effect increased dissolved solids would have on the making of white paper. It is possible they might expand to make white paper in the next 3 to 5 years. It is also possible that they might not expand at all.

Appendix G

Selected Soils, Irrigation, and Fisheries Publications

Soil, Water and Plant Characteristics Important to Irrigation



NDSU EXTENSION SERVICE

FEBRUARY 1996

North Dakota State University, Fargo, ND 58105

Introduction	2
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rrigation, applying water to assure sufficient soil moisture is available for good plant growth, as practiced in North Dakota is called "supplemental irrigation" because it is used to augment the rainfall that occurs during the growing season. Irrigation is used on full season agronomic crops to provide a dependable yield every year. It is also used on crops where water stress affects the quality of the yield, such as flowers, vegetables and fruits.

During most years it is not uncommon for some places in the state to receive sufficient rainfall for good plant growth while other areas experience reduced yields or quality on non-irrigated crops because of water stress from insufficient soil moisture. For irrigation planning purposes, average precipitation during the growing season is not a good yardstick for determining a need for irrigation. The timing and amounts of rainfall during the season, the soil's ability to hold water, and the crop's water requirements are all factors which influence the need for irrigation. Any location in the state can have what might be considered "wet" or "dry" weeks, months and even years.

Under irrigation, soil and water compatibility is very important. If they are not compatible, the applied irrigation water could have an adverse effect on the chemical and physical properties of the soil. Determining the suitability of land for irrigation requires a thorough evaluation of the soil properties, the topography of the land within the field and the quality of water to be used for irrigation. A basic understanding of soil/water/plant interactions will help irrigators efficiently manage their crops, soils, irrigation systems and water supplies.

Soil Properties

Soil surveys of every county in North Dakota have been completed by the Natural Resource Conservation Service (NRCS, formerly the SCS). The county soil survey report provides detailed soils information on any parcel of land and is available from the county NRCS office or the NDSU Department of Soil Science. The soil properties of texture, structure, depth, permeability and chemistry play an important role in irrigation management.

Soil Texture

Soil texture is determined by the size and type of solid particles that make up the soil. Soil particles may be either mineral or organic. In most soils, the largest proportion of particles are mineral and are referred to as "mineral soils." For mineral soils, the texture is based on the relative proportion of the particles under 2 millimeters (mm) or 5/64th of an inch in size. As shown in Figure 1, the largest particles are sand, the smallest are clay, and silt is in between. The soil texture is based on the percentage of sand, silt and clay (Figure 2). Soil texture classes may be modified if greater than 15% of the particles are organic (e.g. mucky silt loam). Soil particles greater than 2 mm in size are not used to determine soil texture. However, when they make up more than 15% of the soil volume, the textural class is modified (e.g. gravelly sand).

Soil texture can be determined by separating and weighing the sand, silt and clay. For example, if a 100 pound sample of soil was sifted through

screens and found to contain 45 pounds of sand, 35 pounds of silt and 20 pounds of clay, then the soil would be composed of 45% sand, 35% silt and 20% clay.

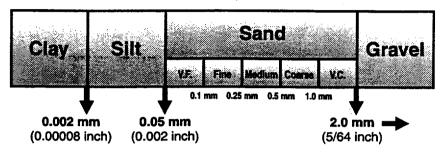


Figure 1. Classification by size of the primary soil particles which define a textural group based on the U.S. Department of Agriculture soil classification system. Under SAND, V.F. refers to very fine and V.C. to very coarse.

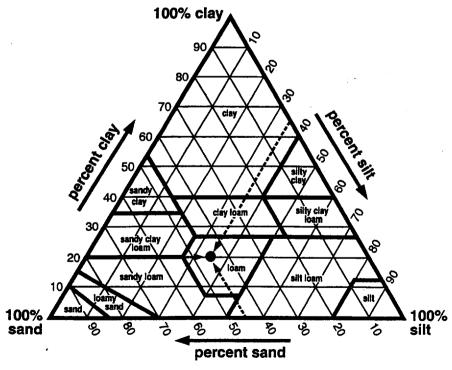


Figure 2. U.S. Department of Agriculture (USDA) soil textural triangle. The percent (by weight) of the sand, silt and clay fraction determines the texture of the soil. The dotted line depicts a loam soil that has 45% sand, 35% silt and 20% clay content.

As shown by the dotted lines in Figure 2, this soil has a loam texture. There are 12 basic soil textures shown on Figure 2. Sand, loamy sands and sandy loams are the most common soil textures irrigated in North Dakota.

Soil Structure

Soil structure refers to the grouping of particles of sand, silt, and clay into larger aggregates of various sizes and shapes. The processes of root penetration, wetting and drying cycles, freezing and thawing, and animal activity combined with inorganic and organic cementing agents produce soil structure (Figure 3). Structural aggregates that are resistant to

physical stress are important to the maintenance of soil tilth and productivity. Practices such as excessive cultivation or tillage of wet soils disrupt aggregates and accelerate the loss of organic matter, causing decreased aggregate stability.

The movement of air, water, and plant roots through a soil is affected by soil structure. Stable aggregates result in a network of soil pores that allow rapid exchange of air and water with plant roots. Plant growth depends on rapid rates of exchange. Good soil structure can be maintained by practicing beneficial soil management such as crop rotations, organic matter additions, and timely tillage

practices. In sandy soils, aggregate stability is often difficult to maintain due to low organic matter, clay content and resistance of sand particles to cementing processes.

Soil Series

Soil is the layer of the earth's surface which has been changed by physical or biological processes. The five soilforming factors that control the process of change are parent material, climate, topography, biota (plants and animals) and time. Soils are grouped into categories according to their observed properties. The USDA classification system consists of six categories. The highest category (soil order) contains 11 basic soil groups, each with a very broad range of properties. The lowest category (soil series) contains over 12,000 soils, each defining a very narrow range in soil properties.

North Dakota has 264 soil series. A soil series is unique because of a combination of properties such as texture, structure, topographic position (on the side of a hill or in a valley) or depth to the water table. A particular soil series describes locations where these soil conditions are similar. These locations may be in the same field, section, county, state or even region. Soil delineations on county soil survey maps are based on the soil series. A soil series is generally named after a town near the site that repre-

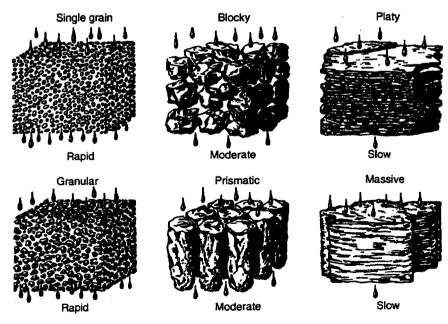


Figure 3. Examples of the most common soil structures. Also shown is the structures' effect on downward movement (infiltration) of water. (Courtesy of the NRCS, Section 15 of the National Engineering Handbook)

sents the typical properties for that soil. For example, the site with typical properties for the Embden soil series is near Embden, North Dakota.

Many soil series do not have a deep, uniform soil profile. Restrictive subsurface layers often interfere with root penetration. In these situations the roots will be concentrated in the upper part of the soil profile. For example, in the Renshaw loam profile (Figure 4), the majority of the plant roots will be in the top 18 inches because of the poor growing environment encountered in the underlying sand and gravel substrata. This type of information is important for irrigation management.

Soil Depth

Soil depth refers to the thickness of the soil materials which provide structural support, nutrients, and water for plants. In North Dakota, soil series that have bedrock between 10 and 20 inches from the surface are described as shallow. Bedrock between 20 and 40 inches is described as moderately deep. Most soil series in North Dakota have bedrock at depths greater than 40 inches and are described as deep. Depth to contrasting textures is given in the soil series descriptions in the county soil survey report.

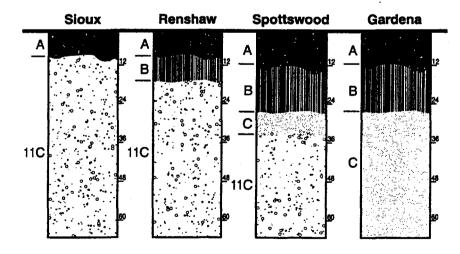


Figure 4. Soil horizon depths for four representative North Dakota soil series. A, B, and C refer to the different soil horizons and IIC indicates a different parent material (for these soil series it is sand and gravel).

The depth to a contrasting soil layer of sand and gravel (Figure 4) can affect irrigation management decisions. If the depth to this layer is less than 3 feet, the rooting depth and available soil water for plants is decreased. Soils with less available water for plants require more frequent irrigations.

Soil Permeability and Infiltration

A soil's permeability is a measure of the ability of air and water to move through it. Permeability is influenced by the size, shape, and continuity of the pore spaces, which in turn are dependent on the soil bulk density, structure and texture. Most soil series are assigned to a single permeability class based on the most restrictive layer in the upper 5 feet of the soil profile (Table 1). However, soil series with contrasting textures in the soil profile are assigned to more than one permeability class. In most cases, soils with a slow, very slow, rapid or very rapid permeability classification are considered poor for irrigation.

Infiltration is the downward flow of water from the surface through the soil. The *infiltration rate* (sometimes called intake rate) of a soil is a measure of its ability to absorb an amount of rain or irrigation water over a given time period. It is commonly expressed in inches per hour. It is dependent on the permeability of the

Table 1. Soil Permeability Classes.

Infiltration Rate (inches/hour)
Less than 0.06
0.06 to 0.2
0.2 to 0.6
0.6 to 2.0
l 2.0 to 6.0
6.0 to 20.0
Greater than 20.0

surface soil, moisture content of the soil and surface conditions such as roughness (tillage and plant residue), slope, and plant cover.

Coarse textured soils such as sands and gravel usually have high infiltration rates. The infiltration rates of medium and fine textured soils such as loams, silts, and clays are lower than those of coarse textured soils and more dependant on the stability of the soil aggregates. Water and plant nutrient losses may be greater on coarse textured soils, so the timing and quantity of chemical and water applications is particularly critical on these soils.

Saline and Sodic Soils

Salt affected soils are grouped according to their content of soluble salts and sodium (Table 2). Saline and sodic soils usually occur in areas where ground water moves upward from a shallow water table close to the soil surface. The water carries salts which accumulate in the soil as the water is evaporated from the soil surface or transpired through the plants to the atmosphere. In general, these soils are not recommended for irrigation.

Saline and sodic soils may be of natural or man-made origins. One of the man-made processes is related to irrigation. Under certain combinations of irrigation water quality and soils, salts and/or sodium may accumulate in the root zone and have an adverse effect on plant growth.

Under some conditions, sodium can be controlled in the upper part of the soil through the use of calcium amendments. The replacement of sodium by

calcium improves the structure of the soil. Calcium soil amendments can be helpful in situations where land with a majority of unaffected irrigable soils contains pockets (inclusions) of sodium affected soils. Under irrigation, calcium soil amendments will help where surface crusting has become a problem. Special irrigation management practices may be required on these soils.

Salt concentrations can be managed by leaching or controlling the water table elevation. Leaching is accomplished by applying more water than the soil will hold within the root zone. Large rainfall events, applying additional irrigation water or both will carry some of the salts below the root zone. Water table control can be accomplished by planting a deep rooted crop, such as alfalfa, or installing subsurface drainage. Deep ditches and tiling are methods of subsurface drainage that have been used successfully

Table 2. Soil chemistry measurements used to classify saline, sodic and saline-sodic soils.

	Electrical Conductivity' (mmhos/cm)	рН	Sodium Adsorption Ratio* (SAR)
Saline soil	greater than 4	less than 8.5	less than 13
Sodic soil	less than 4	8.5 to 10	greater than 13
Saline-Sodic soil	greater than 4	less than 8.5	greater than 13

^{*}Measured from a saturated soil extract

to control the level of the water table in many parts of the world.

Soil salt and sodium contents need to be measured to precisely determine the severity of the problem. The salt content of the soil is estimated from an electrical conductivity measurement using a soil water extract, soil water slurry or soil paste. The sodium content of the soil is often measured on a soil water extract and expressed as the ratio between the sodium and calcium plus magnesium and given the term sodium adsorption ratio (SAR).

Soils can be monitored by soil sampling the surface layer (top 6 inches) on a periodic basis (every three to five years). The SAR of the soil samples will indicate if there is a buildup of sodium. Generally, soils with an SAR of 13 from the saturated extract will exhibit significant physical problems due to dispersal of clay particles. Usually a soil with an SAR of 6 or lower from the saturated extract will not have physical problems associated with dispersed clay. However, if periodic sampling indicates that the SAR is increasing, say from 6 to 9, then it may be time to consider corrective action.

Topography of the Field

Topography or the "lay of the land" has a large impact on whether a field can be irrigated. Relief is a component of topography that refers to the difference in height between the hills and depressions in the field. The topographic relief will affect the type of irrigation system to be used, the water conveyance system (ditches or pipes), drainage requirements and water erosion control practices. The shape and arrangement of topographic landforms and the type of surface waterway network will also influence irrigation management.

■ Slope

Slope is important to soil formation and management because of its influence on runoff, soil drainage, erosion, use of machinery, and choice of crops. Slope is the incline or gradient of a surface and is commonly expressed in percent. The percent slope is determined by measuring the difference in vertical elevation in feet over 100 feet of horizontal distance. For example, a 5 percent slope rises or falls 5 feet per 100 feet of horizontal distance.

In addition to the percent of slope, the shape of the slope is another important characteristic. A convex slope curves outward like the outside surface of a ball, a concave slope curves inward like the inside surface of a saucer, and a plane slope is like a tilted flat surface.

Slopes are described as simple or complex. Simple slopes have a smooth appearance with surfaces extending in one or perhaps two directions. For example, slopes on alluvial fans and foot slopes of river valleys are regarded as simple. Complex areas have short slopes which extend in several directions and consist of convex and concave slopes much like the knoll and pothole topography found on glacial till plains.

Simple slopes of 1% or less are commonly used for gravity (surface) irrigation. Simple and complex slopes greater than 1% should only be irrigated with sprinkler or drip systems. Center pivot sprinkler irrigation systems can operate on slopes up to 15%, but simple slopes greater than 9% are not generally recommended.

To accommodate an irrigation application method such as gravity or sprinkler systems, the slope in a field can be modified by land smoothing. However, land smoothing may cause yield reductions for one to three growing seasons. The places where topsoil was removed are most likely to have yield reductions. Special management of these areas through increased fertilizer and organic matter applications may be required for accelerated recovery.

Irrigation Water Quality

The quality of some water is not suitable for irrigating crops. Irrigation water must be compatible with both the crops and soils to which it will be applied. The Soil and Water Environmental Laboratory in the NDSU soil science department provides soil and water compatibility recommendations for irrigation. Generally a water analysis and a legal description of the land proposed for irrigation are required before a recommendation can be made.

The quality of water for irrigation purposes is determined by its salt content. An analysis of water for irrigation should include the *cations*: calcium, magnesium, and sodium, and the *anions*: bicarbonate, carbonate, sulfate, and chloride. Some crops are sensitive to boron, so it is often included in the analysis.

Irrigation Water Classification

The two most important factors to look for in an irrigation water quality analysis are the Total Dissolved Solids (TDS) and the Sodium Adsorption Ratio (SAR). The TDS of a water sample is a measure of the concentration of soluble salts in a water sample and is commonly referred to as the salinity of the water. TDS is expressed in terms of the

electrical conductivity (EC) and its units are either:

millimhos per centimeter (mmhos/cm), deci-Siemens per meter (dS/m) or micromhos per centimeter (µmhos/cm) where:

 $1000 \mu mhos/cm = 1 mmho/cm = 1 dS/m$

The SAR of a water sample is the proportion of sodium relative to calcium and magnesium. Since it is a ratio, the SAR has no units.

Laboratories that perform irrigation water analysis may provide a suitability classification based on a system developed at the U.S. Salinity Laboratory in California (Figure 5). This classification system combines salinity and sodicity. For example, a water sample classified as C3-S2 would have a high salinity rating and a medium sodium rating. The scale for sodicity is not constant because it depends on the level of salinity. For example, an SAR of 8 is in the S1 category if the salinity is from 100 to 300 µmhos/cm; S2 if the salinity is from 300 to 3000 umhos/cm, and S3 if the salinity is greater than 3000 µmhos/cm.

Much of the water in North Dakota is classified in the C2 to C3 salinity range and the S1 to S2 sodium hazard range. In general, any water with an EC greater than 2000 µmhos/cm or an SAR value greater than 6 is not recommended for continuous irrigation in North Dakota. In cases where sporadic irrigation is practiced (i.e. a particular piece of land is

only irrigated one year out of three or more), lower quality water may be used. However, the lower quality water should not have an EC that exceeds 3000 µmhos/cm or an SAR greater than 10.

Calcium added to irrigation water can lower the SAR and reduce the harmful effects of sodium. The effectiveness of added calcium depends on its solubility in the irrigation water. Calcium solubility is controlled by both the source of the calcium (e.g. calcium carbonate, gypsum, calcium chloride) and also the concentration of other ions in the irrigation water. Compared to calcium carbonate and gypsum, calcium chloride additions will result in higher concentrations of soluble calcium and be the most effective at lowering irrigation water SAR. However, calcium chloride is considerably more expensive than calcium carbonate and calcium sulfate (gypsum).

Carbonates

Carbonate and bicarbonate ions in the water combine with calcium and magnesium to form compounds which precipitate out of solution. Removing calcium and magnesium increases the sodium hazard to the soil from irrigation water. The increased sodium hazard is often expressed as "adjusted SAR."

The increase of "adjusted SAR" over the SAR is a relative indica-

(continued on page 10)

Salinity

C1 - Low salinity water

— can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of slow and very slow permeability.

C2 - Medium salinity

water — can be used if a moderate amount of leaching occurs. In most cases plants with moderate salt tolerance can be grown without special practices for salinity control.

C3 - High salinity water

— cannot be used on soils with moderately slow to very slow

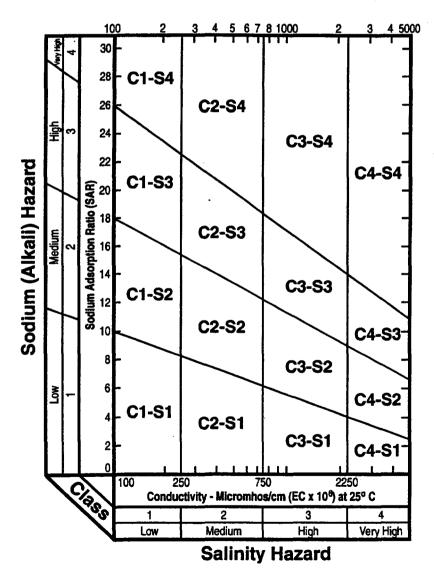


Figure 5. Diagram showing the classification of irrigation water (from Agriculture Handbook No. 60, USDA Salinity Laboratory in Riverside, California).

permeability. Even with adequate permeability, special management for salinity control may be required and plants with good salt tolerance should be selected.

C4 - Very high salinity

water — is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must have rapid permeability, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt tolerant crops should be selected.

■ Sodium

S1 - Low sodium water

— can be used for irrigation on almost all soils with little danger of development of harmful levels of exchangeable sodium.

S2 - Medium sodium

water — will present an appreciable sodium hazard in fine textured soils, especially under low leaching conditions. This water may be used on coarse textured soils with moderately rapid to very rapid permeability.

S3 - High sodium water

— will produce harmful levels of exchangeable sodium in most soils and requires special soil management, good drainage, high leaching, and high organic matter additions.

S4 - Very high sodium

water — is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity.

The Interaction Between Soil and Water

tion of the increase in sodium hazard due to the presence of these ions.

Precipitation of carbonate minerals has not been observed to plug sprinkler systems in North Dakota, but these minerals can cause plugging in drip irrigation systems. To control this problem, the pH of the irrigation water is generally lowered by adding a mild acid.

Boron

Boron is essential for the normal growth of all plants, but the quantity required is very small. Plants sensitive to boron, such as dry beans, require much smaller amounts than plants that are tolerant of boron, such as corn, potatoes and alfalfa. In fact, the concentration of boron that will injure the sensitive plants is often close to that required for normal growth of tolerant plants.

Although there have been no documented problems with boron in water used for irrigation in North Dakota, testing for this element in irrigation water is a precautionary practice. Boron does occur in some North Dakota ground water at concentrations that are theoretically toxic to some crops. Boron concentration greater than 2 parts per million (ppm) may be a problem for certain sensitive crops, especially in years that require large quantities of irrigation water.

Soil is a medium that stores and moves water. If a cubic foot of a typical silt loam topsoii were separated into its component parts, about 45% of the volume would be mineral matter (soil particles), organic residue would occupy about 5% of the volume, and the rest would be pore space. The pore space is the voids between soil particles and is occupied by either air or water. The quantity and size of the pore spaces are determined by the soil's texture, bulk density and structure.

Water is held in soil in two ways: as a thin coating on the outside of soil particles and in the pore spaces. Soil water in the pore spaces can be divided into two different forms: gravitational water and capillary water (Figure 6). Gravitational water generally moves quickly down-

ward in the soil due to the force of gravity. Capillary water is the most important for crop production because it is held by soil particles against the force of gravity.

As water infiltrates into a soil, the pore spaces fill with water. As the pores are filled, water moves through the soil by gravity and capillary forces. Water movement continues downward until a balance is reached between the capillary forces and the force of gravity. Water is pulled around soil particles and through small pore spaces in any direction by capillary forces. When capillary forces move water from a shallow water table upward, salts may precipitate and concentrate in the soil as water is removed by plants and evaporation.

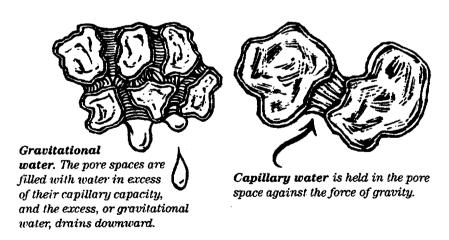


Figure 6. The two primary ways that water is held in the soil for plants to use is by capillary and gravitational forces.

Water Holding Capacity of Soils

There are four important levels of soil moisture content that reflect the availability of water in the soil. These levels are commonly referred to as:

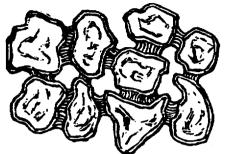
1) saturation, 2) field capacity.

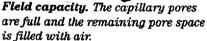
- 3) wilting point and 4) oven dry.
- When a soil is saturated, the soil pores are filled with water and nearly all of the air in the soil has been displaced by water. The water held in the soil between saturation and field capacity is gravitational water. Frequently, gravitational water will take a few days to drain through the soil profile and some can be absorbed by roots of plants.

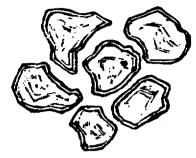
Field capacity is defined as the level of soil moisture left in the soil after drainage of the gravitational water (Figure 7). Water held between field capacity and the wilting point is available for plant use.

The wilting point is defined as the soil moisture content where most plants cannot exert enough force to remove water from small pores in the soil. Most crops will be permanently damaged if the soil moisture content is allowed to reach the wilting point. In many cases, yield reductions may occur long before this point is reached.

Capillary water held in the soil beyond the wilting point can only be removed by evaporation. When soil is dried in an oven, nearly all water is removed. "Oven dry" moisture content is







Wilting point. The water available to plants is exhausted.

Figure 7. Soil moisture available to plants is the amount held between field capacity and wilting point.

used to provide a reference for measuring the other three soil moisture contents.

When discussing the water holding capacity associated with a particular soil series, the water available for plant use in the *root zone* is commonly given (Table 3). Available soil water content is commonly expressed as inches per foot of soil. For example, the water available can

be calculated for a soil with fine sandy loam in the first foot, loanly sand in the second foot and sand in the third foot. The top foot would have about 2.0 inches, the second foot would have about 1.0 inch and the third foot would have about 0.75 inches for a total of 3.75 inches of available water for a crop with a 3 foot root depth.

Table 3. Available Soil Moisture Holding Capacity for Various Soil Textures.

	Available Soil Moisture		
Soil Texture	inches/inch	inches/foot	
Coarse Sand and Gravel	0.02 to 0.06	0.2 to 0.7	
Sands	0.04 to 0.09	0.5 to 1.1	
Loamy Sands	0.06 to 0.12	0.7 to 1.4	
Sandy Loams	0.11 to 0.15	1.3 to 1.8	
Fine Sandy Loams	0.14 to 0.18	1.7 to 2.2	
Loams and Silt Loams	0.17 to 0.23	2.0 to 2.8	
Clay Loams and Silty Clay Loams	0.14 to 0.21	1.7 to 2.5	
Silty Clays and Clays	0.13 to 0.18	1.6 to 2.2	

Soil Moisture Tension

The degree to which water clings to the soil is the most important soil water characteristic to a growing plant. This concept is often expressed as soil moisture tension. Soil moisture tension is negative pressure and commonly expressed in units of bars. During this discussion. when soil moisture tension becomes more negative it will be referred to as "increasing" in value. Thus, as soil moisture tension increases (the soil water pressure becomes more negative), the amount of energy exerted by a plant to remove the water from the soil must also increase. One bar of soil moisture tension is nearly equivalent to -1 atmosphere of pressure (1 atmosphere of pressure is equal to 14.7 pounds per square inch at sea level).

A soil that is saturated has a soil moisture tension of about -0.001 bars, or less, which requires little energy for a plant to pull water away from the soil. At field capacity most soils have a soil moisture tension between -0.05 and -0.33 bars. Soils classified as sandy may have field capacity tensions around -0.10

bars, while clayey soil will have field capacity at a tension around -0.33 bars. At field capacity it is relatively easy for a plant to remove water from the soil.

The wilting point is reached when the maximum energy exerted by a plant is equal to the tension with which the soil holds the water. For most agronomic crops this is about -15 bars of soil moisture tension. To put this in perspective, the wilting point of some desert plants has been measured between -50 and -60 bars of soil moisture tension.

The presence of high amounts of soluble salts in the soil reduces the amount of water available to plants. As salts increase in soil water, the energy expended by a plant to extract water must also increase, even though the soil moisture tension remains the same. In essence, salts decrease the total available water in the soil profile.

How Plants Get Water From Soil

Water is essential for plant growth. Without enough water, normal plant functions are disturbed, and the plant gradually wilts, stops growing, and dies. Plants are most susceptible to damage from water deficiency during the vegetative and reproductive stages of growth. Also, many plants are most sensitive to salinity during the germination and seedling growth stages.

Most of the water that enters the plant roots does not stay in the plant. Less than 1% of the water withdrawn by the plant is actually used in photosynthesis (i.e. assimilated by the plant). The rest of the water moves to the leaf surfaces where it transpires (evaporates) to the atmosphere. The rate at which a plant takes up water is controlled by its physical characteristics, the atmosphere and soil environment.

As water moves from the soil, into the roots, through the stem, into the leaves and through the leaf stomata to the air, it moves from a low water tension to a high water tension (Figure 8). The water tension in the air is related to its relative humidity and is always greater than the water tension in the soil.

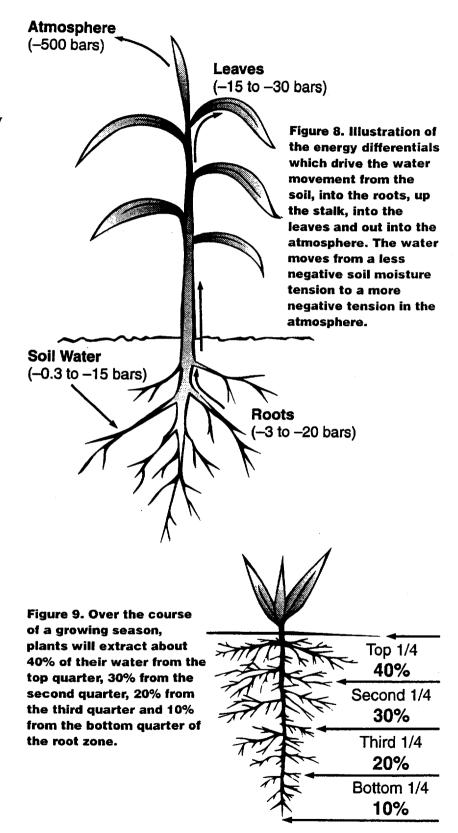
Plants can extract only the soil water that is in contact with

their roots. For most agronomic crops, the root distribution in a deep uniform soil is concentrated near the soil surface (Figure 9). Over the course of a growing season, plants generally extract more water from the upper part of their root zone than from the lower part.

Plants such as grasses, with a high root density per unit of soil volume, may be able to absorb all available soil water. Other plants, such as vegetables, with a low root density, may not be able to obtain as much water from an equal volume of the same soil. Vegetables are generally more sensitive to water stress than high root density agronomic crops such as alfalfa, corn, wheat and sunflower.

Crop Water Use

Crop water use, also called evapotranspiration or ET, is an estimate of the amount of water transpired by the plants and the amount of evaporation from the soil surface around the plants. A plant's water use changes with a predictable pattern from germination to maturity. All agronomic crops have a similar water use pattern (Figure 10). However, crop water use can change from growing season to growing season due to changes in climatic variables (air temperature, amount of sunlight, humidity, wind) and soil differences between fields (root depth, soil water holding capacities, texture, structure, etc.).



Many years of research have produced a number of equations that allow accurate estimates of crop water use values to be calculated from measured daily weather variables. Accurate estimates of crop water use values can be calculated for all the major irrigated crops in North Dakota.

Knowledge of water use patterns during the different growth stages has a major influence on how an irrigation system is designed and managed. Failure to recognize the water use patterns of a crop may result in poorly managed water applications. Crop water stress, fertilizer and pesticide leaching and increased pumping costs are just a few of the results of poor irrigation water management.

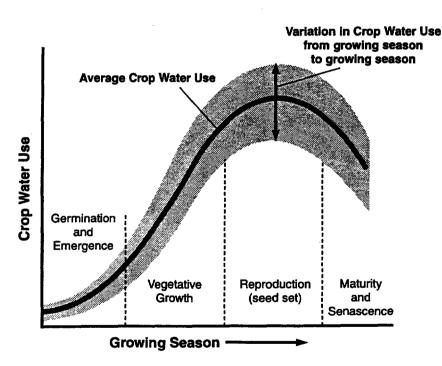


Figure 10. Typical water use curve for most agronomic crops.

Irrigation Water Management

Obtaining increased yield from irrigation requires appropriate management of all the inputs. This means fertilizing to meet the yield goal, good tillage practices and efficient management of the amount of applied water. One of the most difficult parts of irrigation management is deciding when to turn on the irrigation system and how much water to apply. Fortunately, irrigation scheduling methods to help make those decisions have been developed.

Using rational or scientific methods to schedule irrigations is essential for good irrigation management, especially in North Dakota where irrigation is used to supplement rain. Good irrigation management begins with accurate measurement of the rain received on each irrigated field and knowing the soil moisture status in each field at the start of the vegetative growth stage. Over the years, a number of scheduling methods have been developed. Measurement of soil moisture levels has been the most common method of irrigation scheduling, but newer methods use a combination of crop water use and soil water estimates.

The oldest and most commonly used irrigation scheduling method is the "feel method,"

which estimates soil moisture by taking a soil sample in hand and squeezing it into a ball, observing the appearance of the ball and creating a ribbon of soil between the thumb and forefinger to estimate the soil moisture content. This method requires practice and experience to become accurate at predicting irrigation water needs. It is popular because it can be combined with other field activities such as scouting for insects, soil sampling for nitrogen, petiole sampling, etc.

More accurate soil moisture measurement methods use mechanical devices such as tensiometers and soil moisture blocks for irrigation scheduling. These devices are particularly helpful with fruit and vegetable crops and have proven to be accurate, reliable and inexpensive. Other more sophisticated instrumentation can be used for irrigation scheduling but generally are not used for irrigation management because of the expense.

An irrigation scheduling procedure called the "checkbook" method has been used successfully for many years in North Dakota. The checkbook method is a soil moisture accounting method which uses crop water use values and soil water holding capacities to predict the time to irrigate and amount of water needed to replenish what has been removed from the root zone.

North Dakota has a number of automated weather stations which record weather data on an hourly basis. This system is called the North Dakota Agricultural Weather Network (NDAWN). The weather data collected at each station allows calculation of accurate estimates of crop water use values on a daily basis. The crop water use estimates for several crops are available electronically (bulletin board) for each weather station on the NDAWN system and can be used with the checkbook method. This new technology now provides a way to access site-specific estimates of crop water use values.

Additional Sources of Information

Extension Publications

Soil Survey Bulletin (EB-60) Managing Saline Soils in North Dakota (SF-1087)

Salinity and Sodicity in North Dakota Soils (EB-57)

Introduction to Irrigation... A Checklist (AE-92)

Selecting a Sprinkler Irrigation System (AE-91)

Irrigation Scheduling by the Checkbook Method (AE-792) Extension Irrigation Handbook Compatibility of North Dakota Soils to Irrigation from Surface and Groundwater

NRCS Publications

Sources

North Dakota Irrigation Guide County Soil Survey Reports

Compatibility of North Dakota Soils For Irrigation

Dave Franzen
NDSU Extension
Soils Specialist

Tom Scherer NDSU Extension Irrigation Specialist

Bruce Seelig NDSU Extension Water Quality Specialist

How to Use This Information

Irrigation increases the productivity of soils, increases the effectiveness and consistency of certain soil applied herbicides, and provides a more stable supply of farm products to food and feed processors. However, irrigation can degrade the quality of soil and cause crop yields to decline even to the point of field abandonment when soils and water are not compatible. There are examples throughout history of soil degradation and land abandonment due to improper irrigation. When irrigation acreage expands to new areas, determining soil and water compatibility is critical to sustain yields at high levels.

This is intended as a first step to help present and prospective irrigators understand the principles behind the irrigability of soils in North Dakota. This circular should be used in combination with a soil survey of the land to be irrigated. Each soil description may have different phases of slope and other properties which modify its suitability for irrigation. Consultation with a qualified soil scientist is highly recommended before making the decision to irrigate.



NDSU EXTENSION SERVICE

Classification of Soils for Irrigation Suitability

Soil series are classified for irrigation suitability. A soil series is based on distinguishing characteristics including the kind of subsoil layers, or horizons, the depth of each horizon, and the texture, color, carbonate content, sodium content, structure, organic matter and other diagnostic characteristics of each horizon.

Soil series are grouped into three irrigation categories – Non-irrigable (N), Conditional (C), and Irrigable (I). Non-irrigable soils should not be irrigated by any water source and under any circumstance. The decision to classify a soil as non-irrigable is based on the knowledge that irrigation will not benefit the irrigator economically and may decrease the productivity of the soil.

A conditional soil can be irrigated under a high degree of management that will vary according to the quality of water and soil properties. Specific recommendations for conditional soil management are important for sustaining irrigation and soil health for the future.

An irrigable soil can be irrigated with most irrigation water under most circumstances. A high level of management is advised to increase the efficiency of the operation and decrease possible nutrient or pesticide pollution due to excess water movement through the soil.

Some fields will contain soils that fall into two or perhaps all three irrigation categories. Assistance of a qualified soil professional is advised for fields with conditional soils. An irrigation system should be set up to exclude areas that fall into the non-irrigable category, but this may not always be possible. If most of the field falls into the irrigable category, but significant areas are conditional and non-irrigable, management decisions will be strongly influenced by the soils in these catagories. Required management may include annual soil testing for nitrates, sodium and salts, addition of calcium amendments, lower nitrogen fertilizer rates, drainage tile, or other special activities. Special management methods will depend on the reason for placement into conditional or non-irrigable classes.

The special requirements for irrigating small areas of conditional or nonirrigable soils should be part of the estimate of total irrigation costs. From a practical point of view, separate management of these small areas in irrigated fields is not likely to occur. As site-specific farming techniques are developed, more practical methods of managing soil inclusions will become available. Research is underway to develop an irrigation system that will vary the amount of water given to an area under pivot irrigation on-the-go. However, this technology may not be adopted commercially for some time.

Irrigation Suitability Groups

Understanding the irrigability of an area begins with knowledge of local soil series and the way they are represented on a soil survey map. When soil boundaries are drawn on soil maps, the soil mapping unit is not purely one soil. The other soils present are of minor extent and are called mapping unit inclusions. Mapping unit inclusions should be considered when making an irrigation management decision. Soil series have been evaluated and placed into groups called Irrigability Groups.

Finding and using a soil survey

Soil surveys for each county are available through the local NRCS office. Copies of the soil survey for a North Dakota county may also be found in county extension offices, local libraries, the NDSU library and the NDSU Soils Department. The soil survey contains maps that show the different soils on each parcel of land in the county. Information regarding these soils and their use, such as general irrigation suitability is also included in the soil survey. NDSU Extension Bulletin EB-60, Soil Survey: the Foundation for Productive Natural Resources Management, provides details regarding the use of soil survey reports.

Determining the soils within a field is all that is necessary to use the information in this circular. The irrigability classification system and recommendations are based on the North Dakota Irrigation Guide. This document should be referred to for a more comprehensive discussion of soils and irrigation compatibility, compared to the irrigation suitability ratings found in the county soil survey report. Questions about how to use a soil survey can be answered by the local NRCS office or the local county extension office. Reviewing the irrigability ratings with a qualified soil scientist such as a registered North Dakota Professional Soil Classifier is always a good idea before the decision to irrigate is made.

Table 1a. Alphabetical list of soil series, irrigability group and irrigability. Soil type names Aastad - Grassna.

Soil Series	Group	Soil Series	Group	Soil Series	Group
Aastad	C, 3D	Brandenburg	N, 1A/I, 10	Eckman	I, 4A
Aberdeen	N, 2A	Brantford	I, 6A	Edgeley	N, 3C
Absher	N, 1B	Breien	C, 7A	Egeland	I, 7A
Acel	C, 2B	Brisbane	l, 6B	Ekalaka	N, 1B
Alkabo	N, 1B	Bryant	I, 4A	Embden	I, 7A
Amor	N, 3C	Buse	N, 1A/C, 3D	Emrick	I, 4A
Antler	C, 3B	Cabba	N, 1A	Enloe	C, 2C
Appam	I, 8A	Cabbart	N, 1A	Eramosh	C, 2C
Aquents	N, `	Cashel	C, 3B	Esmond	N, 1A/ I, 4A
Arikira	N, 1A	Cathay	N, 2A	Etheridge	C, 2B
Arnegard	I, 4A	Cathro	N, 1F	Evridge	N, 1B
Arveson	C, 7B	Cavour	N, 1B	Exline	N, 1B
Arvilla	I, 8A	Chama	N, 3C	Fairdale	I, 4A
Aylmer	1, 9	Chanta	I, 6B	Falkirk	C, 3D
Baahish	I, 6A	Cherry	C, 3A	Falsen	1, 9
Badland	N, 1A	Chinook	C, 7A	Fargo	C, 2C
Banks	I, 8A	Claire	1, 9	Farland	C, 3A
Bantry	C, 8B	Clontarf	I, 8A	Farnuf	C, 3A
Barnes	C, 3D	Coe	N, 1A/I, 10	Felor	C, 3A
Bearden	C, 3B	Cohagen	N, 1A	Flasher	C, 3A
Bearpaw	C, 2B	Colvin	C, 3B	Flaxton	C, 5A
Beisigl	C, 7A	Cormant	C, 3B	Fleak	N, 1A
Belfield	N, 2A	Cozberg	I, 7A	Foldahl	C, 5A
Benoit	C, 6C	Cresbard	N, 2A	Fordville	I, 6B
Benz	C, 1C	Daglum	N, 1B	Forman	C, 3D
Beotia	C, 3A	Darnen	I, 4A	Fossum	C, 3D
Bigsandy	C, 3B	Desart	N, 1B	Fram	C, 4B
Binford	I, 8A	Dickey	C, 5A	Fulda	C, 2C
Blanchard	I, 8A	Dilts	N, 1E	Galchutt	C, 2C
Blown-Out Land	N, 1A	Dimmick	C, 2C	Gardena	I, 4A
Bohnsack	C, 4B	Divide	C, 6C	Gilby	C, 3B
Borup	C, 4B	Dogtooth	N, 1B	Glendive	I, 7A
Bottineau	C, 3D	Dooley	C, 3D	Glyndon	C, 4B
Bowbells	C, 3D	Doran	C, 2C	Golva	I, 4A
Bowdle	I, 6B	Dovray	C, 2C	Grail	C, 2B
Boxwell	N, 3C	Dupree	N, 1E	Grano	C, 2C
Bowdoin	N, 1D	Easby	N, 1C	Grassna	I, 4A

For explanation of irrigability group, see pages - following. N = nonirrigable, C = conditional, I = irrigable.

Table 1b. Alphabetical list of soil types, irrigabability group and irrigability. Soil type names Great Bend-Oburn.

Soil Series	Group	Soil Series	Group	Soil Type	Group
Great Bend	I, 4A	La Prairie	I, 4A	Makoti	C, 3A
Grimstad	C, 5B	Ladelle	I, 4A	Maladay	I, 7A
Gwinner	C, 2B	Ladner	N, 1B	Mandan	I, 4A
Hamar	C, 2B	Lakoa	N, 1A	Manfred	N, 1B
Hamerly	C, 3B	Lakota	N, 1B	Manning	I, 8A
Hamlet	C, 3D	Lallie	N, 1C	Marias	C, 2B/ N, 1C
Hanly	I, 8A	Lambert	I, 4A	Markey	N, 1F
Harriet	N, 1B	Lamoure	C, 3B	Marmarth	N, 3C
Hattie	C, 2B	Langhei	N, 1A/C, 3D	Marysland	C, 6C
Havre	I, 4A	Lankin	C, 3D	Maschetah	I, 4A
Haverlon	I, 4A	Lanona	C, 5A	Mauvais	C, 3B
Heda	I, 8A	Larson	N, 1B	Max	C, 3D
Hegne	C, 2C	Lawther	C, 2B	McDonaldsville	C, 2C
Heil	N, 1B	Lefor	N, 3C	McKeen	C, 3B
Heimdal	1, 4A	Lehr	I, 6A	McKenzie	N, 1B
Hidatsa	I, 6B	Lemert	N, 1B	Mekinock	N, 1B
Hoffmanville	C, 6B	Letcher	N, 1B	Metigoshe	l, 9
Inkster	I, 7A	Lihen	I, 8A	Minnewaukan	C, 8B
Janesburg	N, 1B	Lindaas	C, 2C	Miranda	N, 1B
Karlsruhe	C, 8B	Linton	I, 4A	Mondamin	C, 2B
Kelvin	C, 3D	Lisam	N, 1E	Moreau	N, 1D
Kensal	I, 6A	Lismore	C, 3D	Morton	N, 3C
Kirby	N, 1A/ I, 10	Littlemo	C, 6B	Mott	1, 7A
Kloten	N, 1E	Livona	C, 5A	Nahon	N, 1B
Korchea	I, 4A	Lohler	C, 2C	Neche	C, 3B
Korell	I, 4A	Lohnes	1, 9	Niobell	N, 2A
Krantzburg	I, 4A	Lonna	I, 3A	Nobe	N, 1B
Kratka	C, 5B	Ludden	C, 2C	Noonan	N, 1B
Krem	C, 5A	Maddock	I, 8A	Nutley	C, 2B
Kremlin	I, 4A	Magnus	C, 2B	Oburn	N, 1B

For explanation of irrigability groups, see pages - following. N = Nonirrigable, C = conditional, I = irrigability.

Table 1c. Alphabetical list of soil types, irrigability group and irrigability. Soil type names Ojata-Zeona.

Soil Series	Group	Soil Series	Group	Soil Series	Group
Ojata	N, 1C	Schaller	I, 8A	Vanda	N, 1C
Oldham	C, 2C	Scorio	C, 2C	Vang	I, 6B
Olga	C, 2B	Searing	I, 6B	Vebar	I, 7A
Omio	N, 3C	Seelyeville	N, 1F	Velva	I, 7A
Osakis .	I, 8A	Sen	N, 3C	Venlo	C, 8B
Overly	C, 3A	Serden	N, 1A/I, 9	Venendrye	C, 8B
Parnell	C, 2C	Seroco	N, 1A/1, 9	Viborg	C, 3D
Parshall	I, 7A	Sham	N, 1D	Viking	C, 2C
Patent	N, 1D	Shambo	I, 4A	Virgelle	C, 5A
Peever	C, 2B	Sinai	C, 2B	Wabek	N, 1A/ I, 10
Perella	C, 3B	Sinnigam	N, 1E	Wahpeton	C, 3B
Playmoor	N, 1C	Sioux	N, 1A/I, 10	Walsh	C, 3D
Poppleton	C, 2B	Southam	C, 2C	Waham	I, 8A
Portal	N, 1B	Spottswood	I, 6B	Wamchaska	1, 9
Rauville	C, 3B	Stady	I, 6B	Wanagan	I, 6A or 6B
Reeder	N, 3C	Stirum	N, 1B	Warsing	I, 6A
Regan	C, 3B	Straw	I, 4A	Watrous	N, 3C
Regent	C, 2B	Suomi	C, 2B	Waukon	C, 3D
Renshaw	I, 6A	Sutley	I, 4A	Wayden	N, 1A
Rhame	I, 7A	Svea	C, 3D	Werner	N, 1A
Rhoades	N, 1B	Swenoda	C, 5A	Wheatville	C, 3B
Ridgelawn	C, 6B	Tally	I, 7A	Whitebird	N, 1B
Rifle	N, 1F	Tansem	I, 4A	Wildrose	C, 2B
Ringling	N, 1A/ I, 10	Telfer	I, 4A	Williams	C, 3D
Rockweil	C, 5B	Temnick	C, 3D	Wilton	C, 3D
Rollette	C, 2B	Tiffany	C, 7B	Wolf Point	N, 1C
Rollis	C, 3B	Tinsley	N, 1A/I, 10	Wyard	C, 4B
Rolla	C, 2B	Toby	I, 7A	Wyndmere	C, 7B
Rondell	I, 4A	Tolna	C, 7B	Wyrene	C, 7B
Roseglen	I, 4A	Tonka	C, 2C	Yawdin	N, 1A
Rosewood	C, 8B	Totten	N, 1B	Yegen	C, 3A
Rusklyn	I, 4A	Towner	C, 5A	Yetull	I, 9
Ruso	I, 8A	Trembles	I, 7A	Zahl	N, 1A/ I, 4A
Ryan .	N, 1B	Tusler	N, 1A	Zeeland	C, 2B
Sakakawea	I, 4A	Ulen	C, 8B	Zell	N, 1A/ I, 4A
Savage	C, 2B	Vallers	C, 3B	Zeona	I, 9

For explanation of irrigability groups, see pages - following. N = nonirrigable, C = conditional, I = irrigable.

Irrigability Groups

In the following text, "<" means less than and ">" means greater than.

Non-Irrigable (NI)

These are soils with very severe limitations due to slope, sodicity, salinity, excessively slow permeability and/or root restrictive subsoil layering. Irrigation is strongly discouraged. Irrigation will cause soil quality to be degraded and reduce the productivity of the soils for future generations of farm producers. Different phases of each soil series will modify irrigation recommendations.

1A. Non-irrigable because of slope

Langhei, slopes >5% Arikara **Badland** Lakoa Ringling, slopes >5% Blow-out Land Brandenburg, slopes >5% Serden, slopes >5% Seroco, slopes >5% Buse, slopes, >5% Sioux, slopes >5% Cabba Tinsley, slopes >5% Cabbart Tusler, slopes >5% Coe Wabek, slopes >5% Cohagen Dumps Wayden, slopes >5% Werner Esmond, slopes >5% Flasher Yawdin Zahl, slopes >5% Fleak Zell, slopes >5% Kirby, slopes > 5%

1B. Non-irrigable because of sodicity

Absher	Exline	Letcher	Oburn
Alkabo	Harriet	Manfred	Portal
Cavour	Heil	McKenzie	Rhoades
Daglum	Janesburg	Mekinock	Ryan
Desart	Ladner	Miranda	Slickspots
Dogtooth	Lakota	Nahon	Stirum
Ekalaka	Larson	Nobe	Totten
Evridge	Lemert	Noonan	Whitebird

1C. Non-irrigable because of salinity

Benz	Lallie	Ojata	Vanda
Easby	Lambeth	Playmoor	Wolf Point

1D. Non-irrigable because of extremely slow permeability

bowdom Moreau Fatent Shan	Bowdoin	Moreau	Patent	Sham
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1E. Non-irrigable because of restrictive subsoil layering

•		
Dilts	Kloten	Livona
Dupree	Lisam	Sinnigam

1F. Non-irrigable because of very poorly drained muck

and peat so	DIIS		
Cathro	Markey	Rifle	Seelyeville

24 Non-irrigable because of high salts in the subsoil

Aberdeen	Cathay	Niobell
Belfield	Cresbard	

3C. Non-irrigable because of shallow depth to bedrock and lateral seepage hazard

Boxwell Lefor Omio Watri Chama Marmarth Reeder	Amor Boxwell Chama	Edgeley Lefor Marmarth	Morton Omio Reeder	Sen Watrous
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Conditional Soils (C)

Conditional soils can be irrigated under a high level of management. Soil conditions which contribute to conditional status are the presence of salts, poor drainage properties, the presence of subsurface layering and the need for supplemental surface and subsurface drainage. Irrigation without high levels of management may degrade soil quality for future generations, but can be successfully irrigated if recommendations are followed. Soil phases of each soil series may modify irrigation recommendations.

2B. Fine-textured, well and moderately drained with moderately or slow permeability and high available water capacity. Classified conditional because of salinity hazard and poor internal drainage.

Acel	Hattie	Nutley	Rolla
Bearpaw	Lawther	Olga	Savage
Etheridge	Magnus	Peever	Sinai
Frazer	Marias	Regent	Wildrose
Grail	Mondomin	Rolette	Zeeland
Gwinner			

Irrigation water quality

Maximum allowable EC <1000 mmhos/cm Maximum allowable SAR <6

Irrigation management

See NDSU Extension Service Circular AE-792 (revised), Irrigation Scheduling by the Checkbook Method, for irrigation scheduling information.

2C. Fine textured soils with poor and very poor drainage and slow, very slow permeability and high available water capacity

Dimmick	Fulda	Lohier	Quam
Doran	Galchutt	Ludden	Southam
Dovray	Grano	McDonaldsville	Scorio
Enloe	Hegne	Oldham	Tonka
Eramosh	Lindaas	Parnell	Viking
Fargo			

Irrigation water quality

Maximum allowable EC <1000 mmhos/cm Maximum allowable SAR <6

irrigation management

See NDSU Extension Bulletin AE-792 (revised) for irrigation scheduling information.

3A. Medium to moderately fine textured. Well drained to moderately well drained with moderately slow permeability and high available water holding capacity. Conditional due to the hazard of salt buildup.

capacity.	onditional due t	o tile hazara e	
Beotia	Farland	Feler	Overly
Cherry	Farnuff	Makoti	

irrigation water quality

Maximum allowable EC <1500 mmhos/cm Maximum allowable SAR <6

Irrigation management

Salinity of the root zone should be monitored every three to five years. Extra water may be required to leach out salts periodically if soil moisture conditions during the fall through early spring do not provide for water movement through the soil. Leaching should be done in the fall or early spring when crop requirements for water are low. The application of ¾ inches of water in excess of field capacity should pass through the crop root zone.

3B. Medium, moderately fine and fine textured, moderately well drained to poorly drained soils with slow to moderately slow permeability and high water holding capacity. Conditional because of the need for supplemental surface and subsurface drainage.

Antler	Flom	McKeen	Roliss
Bearden	Gilby	Neche	Suomi
Big Sandy	Hamerly	Perella	Vallers
Cashell	LaMoure	Rauville	Wahpeton
Colvin	Mauvais	Regan	Wheatville

Irrigation water quality

Maximum allowable EC <1500 mmhos/cm Maximum allowable SAR <6

Irrigation management

Monitor for salinity every 3-5 years. See NDSU Extension Service Circular AE-792 (revised) for irrigation scheduling information.

3D. Medium and moderately fine textured soils, well drained with soft bedrock at 20 to 40 inches, moderate and moderately slow permeability, and high water holding capacity. These soils are conditional due to slow internal drainage and the hazard of salinity buildup.

Aastad	Kelvin	Temvik
Barnes	Kittson	Walsh
Bottineau	Forman	Waukon
Bowbells	Hamlet	Williams
Buse, slope <5%	Langhei, slope <5%	Wilton
Dooley	Lankin	Viborg
Falkirk	Lismore	Zahl, slopes <5%

Max Svea

Irrigation water quality

Maximum allowable EC <1800 mmhos/cm Maximum allowable SAR <6

Irrigation management

Extra water may be required for leaching if fall through spring precipitation does not provide at least ¾ inches of water in excess of field capacity passing through the root zone.

4B. Medium textured, somewhat poorly drained and poorly drained with moderate permeability and high water holding capacity. Conditional because of the need for supplemental surface and subsurface drainage.

Bohnsack Borup Fram Glyndon Wyard

Irrigation water quality

Maximum allowable EC <2250 mmhos/cm Maximum allowable SAR <6

Irrigation management

See NDSU Extension Service Circular AE-792 (revised) for irrigation scheduling information.

5A. Coarse and moderately coarse textured, well to moderately drained soils with glacial till or lake sediments at 20 to 40 inches, moderately slow permeability and moderate water holding capacity. Conditional due to restricted drainage because of subsoil stratification. Salinity should be monitored every 3 to 5 years. Drainage systems may be required for adequate drainage.

Dickey Krem Swenoda Foldahl Lanona Towner Flaxton Livona Virgelle

ririgation water quality

Maximum allowable EC <1800 mmhos/cm Maximum allowable SAR <9

Irrigation management

See NDSU Extension Bulletin AE-792 for irrigation scheduling information.

5B. Moderately coarse textured, somewhat poorly drained and poorly drained soils with glacial till or lake sediments at 20 to 40 inches, moderately slow permeability and moderate water holding capacity.

Grimstad

Kratka

Rockwell

irrigation water quality

Maximum allowable EC <1800 mmhos/cm Maximum allowable SAR <9

irrigation management

Surface and subsurface drains required.

6C. Medium textured, somewhat poorly drained and poorly drained soils with coarse sand and gravel at or just below the rooting zone, moderate to moderately rapid permeability and moderate to low water holding capacity. Conditional because of rapid water movement and need for supplemental drainage.

Benoit

Divide

Marysland

Irrigation water quality

Maxiumum allowable EC <3000 mmhos/cm Maximum allowable SAR <6

Irrigation management

Surface and subsurface drains required.

7B. Medium and moderately coarse textured, somewhat poorly drained and poorly drained soils with moderately rapid permeability and low to moderate water holding capacity. Conditional because of the need for supplemental drainage.

Arveson

Tolna

Wyrene

Tiffany '

Wyndmere

Irrigation water quality

Maxiumum allowable EC <3000 mmhos/cm Maximum allowable SAR <12

Irrigation management

Surface and subsurface drained required.

8B. Coarse textured, somewhat poorly drained and poorly drained soils with rapid permeability and low water holding capacity. Conditional because of the requirement for supplemental drainage.

> Bantry Cormant

Hamar

Poppleton

Vento

Fossum

Karlsruhe Minnewaukan Rosewood Ulen

Verendrve

Irrigation water quality

Maximum allowable EC <3000 mmhos/cm Maximum allowable SAR <12

Irrigation management

Surface and subsurface drainage required.

Irrigable Soils (I)

Irrigable soils need generally less management than conditional soils. Even though the soils are in an irrigable class, good irrigation management is essential. For example, Arnegard, Grassna and LaDelle are in the 4A irrigable class. However, in times of soil wetness, these sites may receive additional water due to surface and subsurface water flow. This additional water may increase salinity and sodicity beyond what might be expected with normal irrigation. Use of lower quality water than recommended can lower the productivity of the soils from salts and sodium. Different phases of each soil series may modify irrigation recommendations.

Medium and moderately fine textured, well and moderately well drained soils with moderate permeability and high water holding capacity.

> Arnegard Bryant Darnen

Havre Havrelon Heimdal

Korchea

Mandan Randell Roseglen Rusklyn

Eckman **Emrick** Esmond, slope <5% Fairdale

Korell Kranzburg Kremlin LaDelle

Sakakawea Shambo Straw Sutley

Gardena Golva Grassna

Lambert La Prairie

Tansem Zell, slope <5%

Great Bend Linton

Irrigation water quality

Maximum allowable EC <2250 mmhos/cm Maximum allowable SAR <6

Irrigation management

See NDSU Extension Service Circular AE-792 (revised) for irrigation scheduling information.

Medium textured, well and moderately well drained soils with coarse sand and gravel at 10 to 20 inches, moderate or moderately rapid permeability, low water holding capacity.

Baahish Brantford Kensal Lehr

Renshaw Warsing

Irrigation water quality

Maximum allowable EC <3000 mmhos/cm Maximum allowable SAR <9

Irrigation management

See NDSU Extension Service Circular AE-792 (revised) for irrigation scheduling information.

Medium textured, well drained soils with coarse sand and gravel at 20 to 40 inches, moderate or moderately rapid permeability, and moderate or low water holding capacity.

Bowdle

Fordville

Littlemo

Spottswood

Brisbane Chanta

Hidatsa Hoffmanville Ridgelawn Searing

Stady Vang

Irrigation water quality

Maximum allowable EC <3000 mmhos/cm Maxiumum allowable SAR <9

Irrigation management

See NDSU Extension Service Circular AE-792 (revised) for irrigation scheduling information.

Moderately coarse textured, well and moderately well drained soils with moderately rapid permeability, moderate water holding capacity.

Conditional due to underlying weathered sandstone 20 to 40 inches Beisigl Breien

Cozberg

Malachy Rhame Vebar

Completely irrigable Chinook Mott

Egeland Parshall Embden Tally Glendive Toby Trembles Inkster Velva

Irrigation water quality

Maximum allowable EC <3000 mmhos/cm Maximum allowable SAR <12

Irrigation management

See NDSU Extension Service Circular AE-792 (revised) for irrigation scheduling information.

Moderately coarse and coarse textured, somewhat excessively to moderately well drained soils. Rapid permeability and low water holding capacity. Some shallow to gravel.

Depth to gravel in parentheses

Appan

Arvilla (12-25 inches)

Lihen Maddock

Banks

Manning (20-40 inches)

Binford (12-25 inches) Breien

Osakis (12-25 inches) Ruso (20-40 inches)

Clontarf Hanly

Shaller Telfer

Hecla

Walum (12-25 inches)

Irrigation water quality

Maximum allowable EC <3000 mmhos/cm Maximum allowable SAR <12

Irrigation management

See NDSU Extension Service Circular AE-792 (revised) for irrigation scheduling information.

9A. Coarse textured soils with rapid permeability, low water holding capacity.

Alymer

Falsen

Seroco, slopes <5%

Blanchard Lohnes

Yetull

Claire

Serden, slopes <5%

Zeona

Irrigation water quality

Maximum allowable EC <3000 mmhos/cm Maximum allowable SAR <12

Irrigation management

Frequent irrigations will be required.

10. Medium to coarse textured, excessively and well drained soils with coarse sand and gravel or porcelainite (scoria) at less than 10 inches, rapid permeability and very low water holding capacity.

(The following soils will fall into group IA if slope is greater than 5%.)

Brandenburg

Kirby

Sioux Wabek

•

Ringling

Tinsley

Irrigation water quality

Coe

Maximum allowable EC <3000 mmhos/cm Maximum allowable SAR <12

Irrigation management

Light, frequent irrigations will be required. These soils may be susceptible to drought even under irrigation.

Important Topographic and Soil Properties Affecting Irrigability

Soil depth

Soil depth depends on the potential rooting depth of plants to be grown and any restrictions within the soil that may hinder rooting depth. The rooting depth of canola may only be about 3 feet, while for alfalfa the rooting depth may be over 4 feet. Discontinuities in the soil from layers of sand, gravel or bedrock may serve to physically limit rooting depth.

Soil texture

The percentage of sand, silt and clay sized particles in the soil is the soil texture. Texture influences other properties such as water holding capacity, infiltration rate and internal drainage.

Soil structure

Soil particles are arranged into aggregates through the action of weather, organic matter attraction, soil mineral composition, time and outside physical forces such as compaction, root growth and animal activities. Soils containing aggregates unstable under irrigation may require special management. Movement of water into and within soils is partially dependent on soil structure.

Water holding capacity

Water holding capacity is defined as the soil water retained between a suction of 0.1-0.5 bars (field capacity) and 15 bars (permanent wilting point). Water held between these two suction values is regarded as plant available water. A silt loam soil holds about 2.25-2.5 inches of water per foot of soil, while a sandy loam can

hold only about 1 inch of water per foot. Soils with higher organic matter generally hold more water than a soil with lower organic matter.

Slope

Slope is important in determining the water runoff potential from a field. Water and soil losses from runoff reduce both short-term and long-term economic returns. Generally, more run-off will occur on fine textured soils compared to coarser textured soils on similar slope.

Infiltration rate

Infiltration rate is the relative rate that water penetrates and moves into the soil. A faster infiltration rate allows less runoff than soil with slower rates.

Internal drainage

Internal drainage describes the degree and persistence of soil wetness and is influenced by slope, soil infiltration rate, soil texture (percent gravel, sand, silt and clay), depth to water table and depth to impermeable layers. Excessively drained soils often have crop production problems related to lack of water and nutrients due to rapid movement of water through the soil profile. On the other hand, soils with poor internal drainage that remain wet may increase disease potential to crops, cause denitrification losses of nitrogen fertilizer or cause accumulation of salts. Soils with good internal drainage respond well to irrigation. Irrigation water is retained for use by crops, while allowing sufficient movement of water within the soil to minimize saturation of pore space.

Salinity

High levels of soil salts usually result from a water table near the soil surface. High salt levels may reduce crop yields and increase the water requirement of plants. Irrigation may decrease the depth to water table over time in some soils, increasing the risk of salinization. Irrigation water containing high salt levels may also increase the risk of salinization. As salinity increases, crop productivity will decrease. Salinity is a soil property that changes relatively quickly with time compared to other properties such as texture. Soil testing for salts is necessary to not only follow possible increases over time in irrigated fields, but also determine if irrigation should be attempted in the first place.

Sodicity

Sodium (Na) affects the physical condition of the soil by dispersing aggregates. The soil becomes pasty when wet and develops a condition called "puddling", where water remains on the surface for an extended period. The soil becomes hard when dry, and its permeability to water and air is reduced. If irrigation causes sodium salts to accumulate near the soil surface, increased sodium levels may cause yield reduction. Sodium buildup usually occurs slowly and may not be easily detected from one year to the next. Regular soil testing is recommended to determine long-term trends in sodium accumulation. Sodium buildup is one of the most serious long term dangers to productivity decline due to irrigating some soils. Water management becomes difficult, seed germination may be poor and roots cannot penetrate well into the soil.

Other More Technical Information

Important chemical characteristics of water affecting irigability of North Dakota soils

Salinity – The salt content of irrigation water is important for the long-term irrigability of many soils. The allowable salt content depends on permeability of the soil, beginning soil salt content, depth to the water table, drainage and texture.

Salts are detected by measuring the flow of electrical current through a sample of soil or water. The more salts in a sample, the less resistance to electrical current and greater the electrical conductivity (EC). Most labs in North Dakota measure conductivity on a 1:1 by weight soil to water slurry. Soils with electrical conductivity greater than 1 dS/cm in the slurry method can decrease the yield potential of some crop plants.

Modification of the water table may be neccessary before irrigation is performed. In areas where salinity is increasing, fertilizer additions should be reduced. Salt problems may be serious enough to discourage irrigation of some fields. See NDSU Extension Service Circular SF-1087, Managing Saline Soils in North Dakota, and EB-57, Salinity and Sodicity in North Dakota Soils, for more information regarding saline soil development and management.

The United States Salinity Laboratory rates salinity in terms of a scale from C1-C4. The definitions of the scale are described below.

Salinity designations of irrigation water:

- C1 (Low-salinity water) Little likelihood that soil salinity will develop. Some leaching may be required, but not more than normal leaching from standard irrigation practices unless the soils are extremely low in permeability.
- C2 (Medium-salinity water) Water can be used if a moderate amount of leaching is used. Plants with moderate tolerance to salinity can be grown without special practices for salinity control.
- C3 (High-salinity water) Cannot be used on soils with restricted drainage. Special management is required even with good drainage. Plants with good salt tolerance must be selected.
- C4 (Very high-salinity water) Not suitable for irrigation except under very special conditions which include permeable soils, adequate drainage, excess water for leaching and very salt-tolerant crops.

Sodicity – The sodium level in the soil in relation to calcium and magnesium, as well as the sodium content of the irrigation water is important to the long-term productivity and health of the soil. Sodium disperses clay particles, causing randomization of clay sheets. Aggregation is poor, resulting in poor water infiltration (ponding) and poor root penetration. Less water and nutrients are available for plant growth.

The amount of sodium in the soil and in irrigation water are also factors which influence sodification. The use of high sodium water depends on the level of salinity and sodicity in the soil and water as described in Figure 1.

The influence of sodium on soil properties depends on the relative amount of sodium with respect to calcium and magnesium. The most accepted method of comparing sodium to calcium and magnesium is by calculating the sodium adsorption ratio (SAR). The SAR may be determined on a soil extract or irrigation water. The calcium, magnesium and sodium content of the sample must first

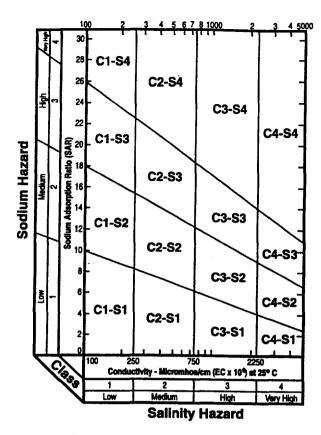


Figure 1. Classificiation of irrigation water (from Agriculture Handbook No. 60, USDA Salinity Laboratory, Riverside, CA).

be measured by a laboratory. After analysis, the SAR can then be calculated using the following formula:

Na⁺ is the concentration of sodium in milliequivalents per liter of soil extract or meq/liter of irrigation water. Ca²⁺ and Mg²⁺ are the concentrations of calcium and magnesium, respectively in meq/liter of soil extract or irrigation water.

A soil extract from a saturated soil with an SAR of greater than 13 is usually an indication of sodium problems and not generally recommended for irrigation.

The SAR, however, is not the only factor to be considered when managing sodicity. The type of anion (chloride or sulfate) in the soil affects the amount of Ca²+ and Mg²+ effective in the soil. The free sulfate in soils high in sulfate may combine with Ca²+ so that the Ca²+ is not available to replace sodium from the soil cation exchange complex. Although an SAR in a sulfate system might suggest a relatively low sodium threat, the effective SAR would be higher. The bicarbonate (HCO₃) or carbonate (CO₃²) content of irrigation water or soil may also cause precipitation of calcium and magnesium carbonates and increase the SAR of the soil.

Texture also modifies the effect of SAR as a management guide. Although an SAR of 13 indicates significant clay dispersion in both a clay loam and sandy loam soil, the actual effect of the dispersion on soil properties is less in the sandy loam. Soils with a relatively low SAR may become dispersed depending on the amount of clay particles held together in part by the attraction of calcium to other clay particles and the dispersing action of sodium which counteracts the aggregation process. See NDSU Extension Service Circulars EB-57 and SF-1087 for more information on sodic soil development and management.

The U.S. Salinity Laboratory defines sodicity in terms of a scale from S1-S4. The definitions of each class are described below.

Sodium designations of irrigation water:

- S1 (Low sodium water) Can be used on nearly all soils with little danger of sodium buildup to the soil, although levels may still be high enough to injure sodium sensitive plants.
- S2 (Medium sodium water) May present a potential sodium buildup on fine-textured soils with low permeability especially if soil free calcium levels are low.
- S3 (high sodium water) May cause sodium buildup in most soils and requires special management, including good drainage, excess water for leaching and organic matter addition. Soils with very high levels of free calcium may not develop problems. Chemical additions (calcium bearing minerals) may be required to replace soil sodium. Chemical additions may not be practical if salinity of irrigation water is high.
- S4 (very high sodium water) Unsuitable for irrigation water except if the water is low or medium salinity (C1 or C2). Under low irrigation salinity, addition of gypsum or calcium chloride may make use of S4 water possible.

Boron — Accumulation of boron has not been documented as an irrigation problem in North Dakota. In a few western states, boron can sometimes be a concern. High levels of boron are toxic to crop plants. Irrigation water should be tested for boron when the well source is originally tested. If the boron level is less than 2 ppm, then boron should not be a problem. If higher than 2 ppm, periodic soil testing every four years would be a good way to monitor boron levels. Water from most North Dakota aquifers is not expected to have high boron levels.

Countering sodium buildup from the use of high SAR irrigation water.

The laboratory derived SAR may not be a clear indicator of the actual dispersion of clay particles due to increased sodium levels or decreased soluble calcium in a soil. A quick field test of suspected problem areas may help direct the need for an amendment. Place a one-half cup of surface soil in a clear glass quart jar, add one pint of distilled water and shake well. Leave the jar undisturbed for 12 hours. If the water has not cleared in that time, the clay has become dispersed and an amendment may be required to keep the surface soil productive.

Sodium accumulation and clay dispersion may be countered by the addition of soluble calcium compounds that replace more weakly held sodium on clay and organic matter surfaces and increase flocculation. Free sodium can then be leached from the soil surface to below the root zone where it will not interfere with plant growth. The hazard of sodium accumulation from irrigation water is illustrated in Figure 1 (USDA, 1954).

The sodicity buildup hazard for irrigation water is dependent on both its SAR and its salinity. As the salt content of the water increases sodicity hazard also increases. This means that lower SARs may cause significant sodium buildup in the soil. The reason for an increased sodicity hazard with greater salinity is simply the greater number of sodium ions to replace calcium in the soil.

The effective use of calcium amendments is related to the salinity and SAR of the irrigation water and the soil mineral content. Addition of calcium amendments to irrigation water may be most helpful with irrigation water classes C1-S3, C1-S4, and C2-S4. The sodicity hazard of irrigation water classes C1-S3 and C1-S4 may be reduced with the addition of calcium amendments to irrigation water. Application of soluble calcium amendments may be most useful with soils irrigated with water in classes C2-S3 and C3-S2.

Calcium amendments for soil and irrigation water

Gypsum, which is the common name for calcium sulfate (CaSO₄), has been used successfully as a reclamation amendment when the soil was not already saturated with gypsum. In areas with low soil salt content, gypsum is the preferred method of reclaiming high sodium soils. Gypsum dissolves in the soil and calcium ions replace sodium ions on clay and organic matter surfaces.

Water moving through the soil then leaches the sodium out of the root zone. However, in many North Dakota soils, sodium and calcium levels are high together. Addition of gypsum in soils already high in gypsum will not result in a replacement of sodium, since greater amounts of gypsum will not increase the number of free calcium ions in solution. Other amendments may be more useful.

In soils with high levels of calcium carbonate and low levels of gypsum, application of elemental sulfur is sometimes used to produce gypsum. Sulfur is oxidized in soils by sulfur bacteria. The resulting sulfuric acid reacts with calcium carbonate to produce gypsum.

In some soils, subsurface gypsum layers can be incorporated into surface soils with high sodium levels through deep tillage. Mixing gypsum into high sodium soils may be a practical way to reclaim some soils. Before tillage, soil sampling surface and deep layers with respect to sodium and gypsum levels will be necessary. If excess gypsum is not present in the subsurface layers, deep tillage may not be helpful.

More soluble calcium amendments, such as calcium chloride, may be more useful in replacing sodium ions in sulfatic systems. Calcium chloride is more soluble in sulfatic systems than gypsum. The economics of reclamation and effectiveness of amendments in reclaiming sodic soils or countering sodium accumulation should be evaluated before deciding to use a soluble calcium amendment.

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REFERENCES

- Franzen, D., C. Fanning and T. Gregoire. 1994. Managing saline soils in North Dakota. NDSU Ext. Bull. SF 1087.
- Scherer, T.F., B. Seelig and D. Franzen. 1996. Soil, water and plant characteristics important to irrigation. NDSU Ext. Bull. EB-66.
- Seelig, B. 1993. Soil survey: the foundation for productive natural resource management. NDSU Ext. Bull. 60.
- Seelig, B.D. and J.L. Richardson. Salinity and sodicity in North Dakota soils. NDSU Ext. Bull. EB-57.
- Sylla, M. 1983. Greenhouse reclamation of salt-affected soils of ND. MS thesis. NDSU.
- U.S. Salinity Laboratory Staff. 1954. Diagnosis and improvement of saline and alkali soils. Agric. Hanb. No. 60, USDA. U.S. Gov. Print. Off., Washington, D.C.



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Managing Soils n North Dakota

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Salt Accumulation Processes

Saline soils are soils which have salf levels high enough that crop yields begin to suffer. Excessive salts injure plants by disrupting the uptake of water into roots. Several factors contribute to the development of high water table saline soils in North Dakota. Recognizing how and why salts accumulate is the first step in farming profitably on land interspersed with salty ground.

The weathering of geologic materials has given rise to our present soils and left the salts that impact crop growth and vield. Lack of leaching has kept the salts from leaving. The pattern of saline soils across the state results from years of natural salt redistribution. However, farming practices can influence the spread and severity of saline soil acreage. A survey of growers from Hettinger County in 1968 showed that 51 percent of the reported saline soils had appeared within the eight years prior to the survey

Leaching of salts into a shallow water table over time has created shallow saline groundwater in wide areas of the state. Water flows downgrade due to gravity. Salts are often concentrated at or near the surface by capillary flow. In capillary flow, water moves from where the soil is saturated, or nearly so, to drier soil independent of gravity, much like water moving into a dry sponge from a puddle of water on a table. Evaporation then dries the soil and "pulls" water by capillary flow from the wet soil zone. When the water evaporates, salts are left behind.

In clay soils, this rise can reach 4 to 5 feet above the water table. In sandy soils, which have larger pore sizes between soil particles, the pull is less, perhaps reaching 2.5 to 3 feet above the water table (Figure 1). Water movement toward the surface through capillary rise provides a continuous supply of salts which ac-

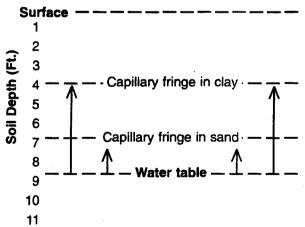


Figure 1. Capillary rise from a 9 foot water table depends on soil texture. Capillary rise will extend higher in a clay soil than in a sand.



cumulate in the root zone or at the soil surface when the capillary water evaporates.

Groundwater produces a crop production paradox. Crops can use some residual groundwater to supplement precipitation received during the growing season. However, groundwater too close to the surface can carry salts as well as water into the crop root zone, causing yield reductions and crop failures. Management of these soils must somehow balance seasonal water needs with salt reduction.

Figure 3 shows surface salt accumulation due to seasonally wet soils. A feature found in seasonally wet saline soils is a relatively low area with white, crusty, salty material, surrounded with sparse crop growth and a sharp boundary where crops grow reasonably well. It is common when examining soil in these low areas to see pockets of crystalline salts in the plow layer. A subsoil sample beneath the fringe crop plants surrounding the bare area often reveals salt crystals

The Nature of North Dakota Salts

The salts most commonly found in concentrations that affect crop growth are sodium sulfate (Na₂SO₄) and sodium chloride (NaCl). North Dakota's saline soils are usually a mixture of the two salts, with sodium sulfate being the most dominant form.

Sodium chloride is the dominant salt in most saline soils of the world. It accumulates in oceans and in sea water sediments. Sodium chloride is also the dominant salt in the saline soils of eastern Grand Forks County. Artesian flow from geologic deposits with residual sea water has added sodium chloride to shallow ground water in that area.

Saline soils develop where the evaporation exceeds the growing season rainfall, and local landscape features accumulate seasonal runoff to form a water table which at some point rises to less than 6 feet below the soil surface. The Northern Great Plains of the United States and Canada have vast areas that meet these criteria and where saline soils are common.

Where Do Salts Accumulate?

Figures 2a, 3 and 4 provide examples of where salts are commonly found in North Dakota landscapes due to high saline water tables. It is common for potholes and slow moving natural drains to have an accumulation, as shown in Figure 2, a short distance back from the water's edge. In this example, water can move laterally over a long period of time, flushing the soil of salts as it moves and concentrating these salts at the maximum depth above the water table where the capillary water rises and then evaporates. This condition is also common along road ditches, field ditches, and next to sewage lagoons.

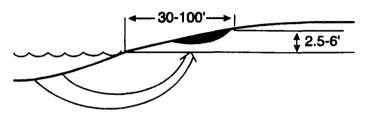


Figure 2a. Saline soil development near shallow streams, road ditches and sewage lagoons.

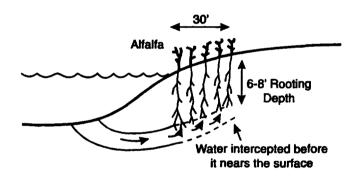


Figure 2b. Use of a 30 foot alfalfa strip along borders of shallow stream, road ditch or sewage lagoon prevents fringe salt deposition.

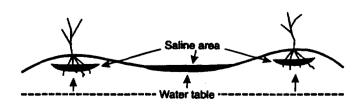


Figure 3. Saline development in a nearly level landscape with a shallow, saline water table. Continuous cropping will help decrease development.

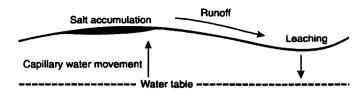


Figure 4. Saline development on a high clay content, subtly undulating landscape. Salt accumulates on high clay content ridges, while the low spots are leached of salts. Continuous cropping will help lower water table and stop saline development.

there, also. However, crops in the depression edge usually grow normally. In this example, the crops rooting into the capillary fringe have enough water, but, through drying of the soil around the roots, accumulate salts at the top of the capillary fringe, somewhere below the surface.

Figure 4 shows a condition in a subtly undulating landscape with a high soil clay content. This landscape usually would have an elevation difference of only 6 to 8 inches from top to bottom. Rainfall runs off the slowly permeable clay into the microrelief depressions in between the higher elevations. Water then leaches out the salts in the depressions. Groundwater containing salt rises through capillary flow to the highest soil surface.

In addition to these conditions, North Dakota also has large areas where a shallow water table lies under a relatively flat soil surface. Subsoil salt accumulation in these areas is wide spread. High rainfall years raise water table levels, which bring salts to or near the surface, adversely affecting crop growth. Following drought and a lower water table, rains leach the salts to a lower depth. As the salts are washed lower, the salt concentration in the rooting zone is decreased and crop growth benefits.

Another serious saline soil problem, especially in hillier regions of North Dakota, is saline seeps. These areas are described by Seelig and Richardson, 1991, and the formation and management required to work with these soils will not be discussed here. Seelig and Richardson also give much more detail concerning the development of saline soils than have been described in this bulletin.

Saline Soil Management

Tile Drainage

In the parts of the world which have natural, well developed drainage systems, the simplest way to solve a saline soil problem is to install tile drainage in the problem fields, leaching low-salt water through the soil profile, and thereby allowing the salts in the field to be carried away from the field and into drainage canals or natural waterways by the tile water. However, in most areas of North Dakota tile drainage is not an option.

Most saline affected soils in the state have no suitable natural drainage, with natural elevation falls of less than 1 foot per mile in many areas. The rivers, besides being slow and meandering, also drain into Canada and South Dakota, which do not particularly want more salt in their river systems.

Even if drainage was a possibility, tile construction within fields is expensive. A tile system in an Illinois clay loam soil, for example, requires parallel tile line about 200 feet apart, with a cost of approximately \$500 per acre. This cost is nearly twice what some farmland in North Dakota is appraised at.

Fortunately, researchers studying the salinity problem in the Northern Great Plains have more practical management plans which should increase productivity of saline affected soils and reduce their acreage over time.

Tillage and seedbed preparation

Stand establishment is a critical crop yield factor for all crops, especially in saline soils. Salts affect germination and emergence in a manner similar to seedbed drying. Stand loss from poor emergence is directly proportional to soil salt concentrations beyond a relatively low threshold level. Many crops are much more sensitive to salt levels as a germinating seed and seedling than as an established plant (Table 1). Once a plant is established, it is normally more tolerant of higher salt levels.

Table 1. Relative sensitivity to salts of germinating and established crop plants.

Crop	Salt Tolerance of Germinating Plants	Salt Tolerance of Established Plants			
Barley	high	high			
Rye	high	medium			
Com	medium	low			
Wheat	medium	medium			
Alfalfa	low	medium			
Sugarbeets	very low	medium			
Beans	very low	very low			

Salt levels in a seedbed can often be managed to acceptable limits. Seeding of spring seeded crops on saline soils should be delayed as long as practical to take advantage of the leaching potential of spring rains. One inch of rainfall can reduce salt concentrations by 50 percent in the 1- to 2-inch seedbed required for most crops grown in North Dakota. Lowering the salt concentration in the seed planting zone can give a dramatic increase in seed germination and seedling survival.

No-till or reduced/minimum tillage systems which allow only shallow tillage are recommended for seed-bed preparation in saline soils. Salts leached away by winter snow melt and spring rains can be returned to the surface by deep spring tillage. Fall tillage should also be evaluated on the basis of spring seedbed preparation needs and relative salt levels in the tillage depth. Most deep tillage operations on saline land unneccessarily increase surface salt concentrations.

Soil testing for salinity

Soil areas that are severely affected by salts often have a bright white, crusty appearance when dry. The extent of severity of the saline area usually extends well beyond the obvious area. In areas lacking a surface crust or obvious vegetation loss, the salts are dissolved in the soil water and cannot be seen. Therefore, the extent of the problem can only be identified with a soil test.

Soil testing laboratories use the electrical conductivity (EC_e) of a soil extract to measure salt concentrations. There are handheld conductivity meters available which, when properly calibrated, can be used to make field measurements quickly and help define saline area boundaries. These field determinations are important, because often when a composite soil sample is taken, areas of high and low salt are mixed, giving an unrepresentative picture of the field.

Several measurements should be taken in the suspected saline areas just outside the area, and at some distance surrounding the area in order to properly map the field. Field EC_e levels can be extremely variable within short distances. Knowing what the salinity patterns are in the field and how extensive they are can greatly influence a management strategy.

Table 2. Crop salinity tolerance rating, field crops (Maas, 1986; Maianu and Lukach, 1985: Maianu. 1983: Maianu. 1984).

Стор	Threshold Salinity		% Yield decrease	EC, at 70% yield	Relative tolerance				
	1:1 soll- water Past Slurry dS/m		Saturated paste extract % per dS/m	este paste S tract extract			M T	Т	
Alfalfa	1.6	2.0	7.3	6.1			Х		
Barley**	2.2	5.2	8.6	8.5				X	
Beans, dry	0.7	1.0	19.0	2.6	X		l		
Com	1.0	1.7	12.0	4.2		Х	•		
Flax	1.0	1.7	12.0	4.2		Х	ļ		
Millet	-	-	-	-		X	ŀ		
Oats*	j -		6.4	-			х		
Potato	-	1.5	14.0	3.6			Х	İ	
Rape*	l -	-	8.4	-			×		
Rye*	-	-	5.7	11.2			Х		
Safflower*	-	-	6.4	7.2			X	ŀ	
Soybean****	2.2	7.5	21.3	9.0			Х		
Sudan grass	-	2.8	4.3	3.6			Х		
Sugarbeet	3.0	7.0	5.9	9.8]			Х	
Sunflower	1.3	2.5	3.4	11.3			Х		
Wheat***	2.5	5.5	8.0	8.3			Х	ĺ	
Wheat, Durum	2.2	5.9	3.8	13.8				Х	

^{*%} Yield decrease and 70% loss in yield dS/m values from Holm, 1979. S=sensitive, MS+moderately sensitive, MT+moderately tolerant and T+tolerant.

^{**}From Maianu and Lukach, 1985.

^{***}From Maianu, 1983.

^{****}From Maianu, 1984.

Electrical conductivity is a low cost analysis. The results are either reported as decisiemens/meter (dS/m) or as millimohs/cm (mmohs/cm). One dS/m equals one mmoh/cm, so the terms are equivalent. Data, charts and papers can be found which use both terms.

Laboratories measure EC_e on different soil to water extracts because of their convenience to the laboratory. The most common measurements are made on extracts from either a saturated paste or a 1:1 by weight soil-to-water slurry. The saturated paste extraction is more precise but is time consuming and expensive. The 1:1 soil water paste is a simple, rapid, low cost and excellent procedure for screening problem soil sites and is the procedure used by the NDSU soil laboratory.

Results can roughly be converted back and forth from a 1:1 slurry to a saturated paste, using the following formulas where $y = EC_e$ of a 1:1 soil-to-water slurry and $x = EC_e$ of a saturated paste extract. These formulas are not well calibrated and should only be used as a rough guide.

Soil Texture

Coarse	Medium	Fine
x = 3.01y-0.06	3.01y-0.77	2.96y-0.95
y = 0.33x + 0.06	0.33x+0.77	0.375x+0.97

Crop tolerance

Crops have different tolerance levels for salt concentrations. All crops have a maximum salt level they can tolerate without a yield loss. Salt levels above a crop's maximum tolerance level sharply reduce yields.

The generally accepted soil salinity ratings for field crops, pasture and hay grasses and vegetables are shown in Tables 2 through 4, respectively. The tables show tolerance levels for both 1:1 soil to water slurry as well as saturated paste extracts.

This information is from established plants. As shown in Table 1, crops are often more sensitive at germination and early crop growth. Some varieties within each crop are more tolerant to salt than others. Local agronomists and seed suppliers can help select the best varieties. The percent of decrease in yields for

Table 3. Crop salt tolerance ratings, pasture and hay grasses (Maas, 1986).

Стор	Thresho	id Salinity	% Yield decrease	EC _e at 50% yield	Relative tolerance			
	1:1 soil to water slurry dS/m	Saturated paste extract dS/m	% yield loss per dS/m	dS/m	MS	MT	Т	
Alkaligrass, nuttal	-	-	-				Х	
Alkali sacton	•	-	-	-			X	
Brome, smooth	•	-	-	-	x			
Fescue, tall	•	3.9	5.3	13.3	1	X	ļ	
Gramma, blue	•	-	-	-	X			
Ryegrass, perennial	2.1	5.6	7.6	12.2		Х	1	
Timothy	-	-	-		l x	,	1	
Wheatgrass, fairway crested	2.8	7.5	6.9	14.7			×	
Wheatgrass, intermediate	•	-	-	<u> </u>		X		
Wheatgrass, slender	-	-				X		
Wheatgrass, tall	2.8	7.5	4.2	19.4			x	
Wild rye, beardless	1.2	2.7	6.0	11.0		Х		
Wild rye, canadian	-		-	-		X		
Wild rye, russian	_	-					Ιx	

MS=moderately sensitive, MT=moderately tolerant, T=tolerant

Table 4. Crop salt tolerance ratings, vegetables (Maas, 1986).

Сгор	Thresho	d Salinity	% Yield Decrease	EC, at 70% yield	Relative tolerance			
	1:1 soil- water Slurry dS/m	Saturated paste extract dS/m	% Yield loss decrease per dS/m	dS/m	S	MS	MT	
Bean	0.6	1.0	19.0	2.5		Х		
Cabbage	0.8	1.8	9.7	4.9		Х		
Carrot	0.6	1.0	14.0	3.1	X			
Corn, sweet	0.8	1.7	12.0	3.4		Х	l	
Cucumber	1.0	2.5	13.0	3.6		Х		
Lettuce	0.7	1.3	13.0	3.6		X	ļ	
Onion	0.6	1.2	16.0	3.3	х			
Pea	1 -			-	x			
Pepper	0.7	1.5	14.0	3.6		X		
Potato	0.8	1.7	12.0	4.2		X		
Pumpkin	-		-			X		
Radish	0.6	1.2	13.0	3.3		X		
Squash, Zucchini	1.8	4.7	9.4	7.9			Х	
Strawberry	0.6	1.0	33.0	1.9		X		
Sweet Potato	0.7	1.5	11.0	4.2		Х		
Tomato	`1.1	2.5	9.9	5.5		X		
Turnip	0.5	0.9	9.0	4.2		X		
Watermelon	-		-			X		

S=sensitive, MS=moderately sensitive, MT=moderately tolerant.

Table 5. Relative yields at increasing soil salinity (Holm, 1979.)

Crop			E	ectrica	l condu	ctivity,	ED _{e'} d	S/m, sa	turated	paste.		
	2	4	6	8	10	12	14	16	18	20	22	24
Soybeans	87	53	27	7	0		-		•	-	-	-
Pinto beans	100	80	54	28	0	-	-		-	-	-	
Alfalfa	100	8 5	68	56	44	36	28	23	17	13	8	4
Oats	90	65	40	28	22	16	11	7	3	0	•	-
Corn	97	70	43	23	5	0	-	-	-	-	•	-
Hard red spring wheat	100	88	64	45	25	14	6	0	-	-	•	-
Durum wheat	100	100	87	72	52	32	17	8	0	-	-	
Barley	100	100	92	76	60	44	30	16	7	0	-	-
Corn, forage	100	90	66	45	28	19	14	8	5	2	0	
Flax	100	87	70	55	41	29	20	12	4	0	-	
Sunflowers	100	97	86	71	55	40	27	17	10	2	0	
Sugarbeets	100	100	100	97	80	64	45	32	23	16	11	7

each dS/m above the saturated paste extract maximum tolerance level for each crop is listed. Also, the saturated paste extract level which would give 70 percent of maximum yield was also calculated and listed.

The crops listed in Tables 2 through 4 have also been grouped into the four tolerance groups; 1)sensitive, 2) moderately sensitive, 3) moderately tolerant and 4) tolerant. This tolerance grouping has been used by several researchers as a management aid for growers on saline soils. Tolerance of selected crops to increas-

ing salt levels is summarized in Figure 5. The salt scale is also converted to the NDSU laboratory EC_e units, 1:1 soil to water slurry.

More specific information concerning individual crops is graphically displayed for highly tolerant crops in Figure 6, legumes in Figure 7 and cereal crops in Figure 8. These three figures have also been summarized in table form in Table 5. Selecting a proper crop and understanding its limitations in a specific saline soil can increase farming profits on that land.

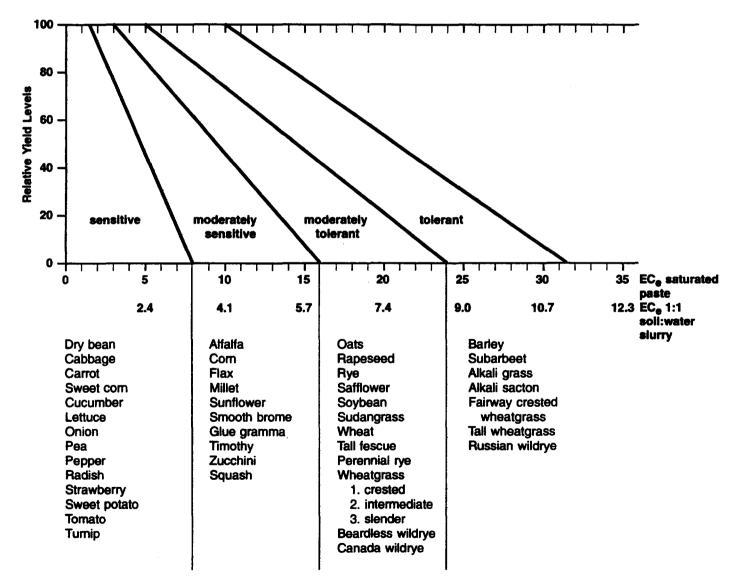


Figure 5. Crop tolerance groups and generalized relative yields with increasing salt levels in moist medium textured soils.

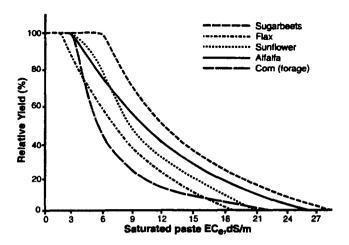


Figure 6. Relative yields of highly salt tolerant established frops at increasing salinity levels. (Holm, 1979).

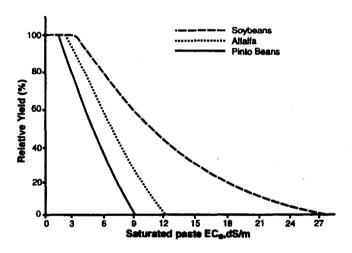


Figure 7. Relative yields of selected legumes at increasing salinity levels (Holm, 1979).

Lower the water table and lower salinity risks

The key to managing saline soils is to control the flow of saline water into the crop root zone. When the source of saline water is a shallow water table, the management tool is to lower the water table. Since drainage is seldom an option in North Dakota, the solution is to continuously crop, using late-maturing, deep-rooted crops in the rotation.

A crucial element in successful salt reduction in a continuously cropped system is to eliminate bare or black summer fallow. Water use efficiency of fallow ranged from only 0 to 18 percent of rainfall during a five-year study. The researchers found that some water evaporated, but some contributed to groundwater below 4 feet in depth. If the soil profile is dry enough, however, the loss to groundwater is minimal and certain soils would retain more infiltrated water in the upper 4 feet in the spring. The study found that fallowing in a loam-textured soil when soil moisture before planting was less than 4 inches in the top 4 feet did not contribute excess water to groundwater. Soil moisture levels of 4 inches of available water in the upper 4 feet in a loam soil is about 25 percent of field capacity. Extending this principle to a sandy loam would not be appropriate, since the possible water holding capacity of a coarser soil is often not much more than 4 inches, so significant rainfall is rapidly moved to deeper depths.

It would be rare to have soil moisture levels low enough in the spring that fallow would not result in

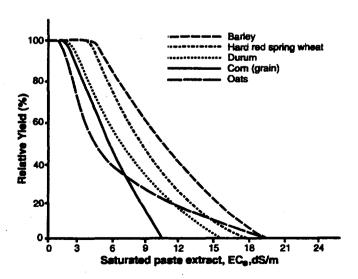


Figure 8. Relative yields of selected cereal crops at increasing salinity levels (Holm, 1979).

seasonal losses of added precipitation to groundwater. When spring moisture levels are sufficient for crop production, the chances of salt reaching the rooting zone are very high and fallow should not be used.

A late-maturing, deep-rooted crop with salt tolerance would be a good choice to help lower the water table. Deep-rooted, salt-tolerant crops can use saline groundwater. Figure 9 shows that crops use significant amounts of water from the water table, lowering it over time.

Several studies have shown the value of alfalfa as an excellent choice to help lower the water table. Alfalfa should be used as a part of a rotation or as a permanent water barrier when it is neccessary to control the flow of salt water from one soil to another. Along ditches, potholes and intermittent streams, a 30-foot strip of alfalfa will use enough water that salts are kept from nearing the surface (Figure 2b). In situations where the water table is too high, alfalfa will lower it better than any other crop. In recharge areas, alfalfa can use a large amount of water before it has a chance to discharge farther down slope.

Other possible rotational crops are sunflower and safflower. However, they are not as good as alfalfa in using water because of their relatively short growing seasons.

Sweet clover would be an excellent green manure crop which would help on fallow by lowering the water table and supplying nitrogen for the next crop. Water use by sweet clover is often great enough to reduce

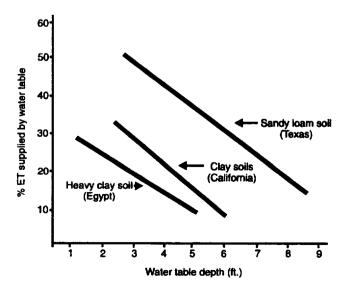


Figure 9. Evapotranspiration supplied by a saline water table as affected by water table depth.

yields the following season. Proper management will reduce this risk. If a green manure was used, a shallow tillage instead of plowing would be recommended, so that salts are not returned to the surface.

There may be years when, despite the best water table management, excessive rainfall could again raise the water table close to the surface. However, the chances of this event would be greatly reduced if the water table was lower initially. Lowering the water table should be viewed as a long term management tool, and neither a quick nor permanent renovation technique.

Late-maturing crops with deep rooting properties are important for saline soil management for the following reasons:

- Late-maturing crops provide a mulching soil cover until frost, reducing the potential for late summer and early fall surface evaporation.
- Deep-rooted crops leave the soil drier at deeper depths going into the winter, increasing the potential for salts to leach away from the soil surface.
- Deep-rooted crops can use more water at the capillary water boundary, preventing further upward movement.

In a recharge area, which is the source of the water which carries salts to a discharge site, a perennial, deep-rooted crop is best at limiting discharge. The next choice is a deep-rooted, long season annual. The third choice is any annual crop. The following crops are ranked by their potential contribution to limiting salt water discharge from a recharge area: alfalfa>sweet clover>sunflower, safflower>barley, wheat, soybean, durum wheat and canola.

A crop rotation could be designed so that a combination of perennial and annual crops could be used to diversify the system to meet goals of improved soil quality and profitability. The most important point, no matter what cropping system is used, is to continuously crop the recharge area with something green for as long a period as possible.

In the discharge area, a salt-tolerant crop will be the only crop which can be grown. A list of crops and general crop tolerances are given in Tables 2-4. These lists are very general. There may be situations when the most salt-tolerant crops do not perform well in these areas. There may be other situations in which sensitive crops do quite well. There will also be differences between varieties of the same crop. Informa-

tion concerning the salt tolerance of specific varieties should be obtained from a commercial seed source before making a selection. It will also be important to note Table 1, which shows that there are differences in the ability of crops to tolerate salt at germination and later on. Sugarbeets, once established, are one of the most salt-tolerent crops available, but, they are very sensitive to salt levels at germination.

Managing Sodic Soils

Many saline soils in North Dakota also have elevated levels of sodium. High levels of sodium restrict waterholding capacity in two ways. First, sodium prevents soil clay particles from gathering together into small groupings. This process of gathering together is called flocculation. Flocculation allows water to penetrate between the groups of soil particles and provide moisture to deeper depths. When sodium levels are high enough to prevent flocculation, the individual clay particles overlap each other randomly during wet conditions, preventing water penetration through the high sodium layer.

Secondly, when the soil dries out, areas within high sodium soils form hard structures which look like round-topped columns. These columns do not allow roots to penetrate into the column, so the only water and nutrients which are available to plant roots come from the small surface area surrounding these structures. The plants are therefore allowed only a small percentage of the total possible volume of soil in which to grow.

Areas of high sodium can be suspected when soil pH is greater then 8. The areas can be confirmed by requesting a sodium test. Most laboratories equipped to analyze for potassium are also equipped for analyzing sodium.

The spread of high sodium areas can be checked by following the same management plan as for any salt

problem. Decreasing the level of sodium may be much more difficult, however. Because of the restriction of water movement within the soil, leaching is more difficult.

If high levels of gypsum are present in the soils with high sodium, addition of gypsum will not help replace sodium in the soil. In these soils, deep plowing may help to mix the gypsum already present in the soil with the sodium bearing soil horizons. If the soils do not already contain gypsum, addition of gypsum will replace sodium with calcium in the profile.

Calcium chloride will perform an even faster remediation than gypsum. Calcium chloride is more soluble than gypsum, therefore needing less water to replace sodium within the profile. If the local economics are favorable for a calcium chloride application, it is the preferred sodic soil remediation amendment. Together with enough water and a deep enough water table which would allow sodium to leach away from the root zone, the soil can be improved by this amendment procedure. Sodic soil remediation should consider calcium chloride first and gypsum second when making a decision. It is important to note that any amendments and management will be ineffective in controlling sodium if the water table management recommended for salt management is not implemented at the same time.

Summary of Saline Soil Management Tools

- 1. Soil test for salinity levels and the extent of the problem in each field.
- 2. Select the right crop and variety for the situation.
- 3. Use shallow tillage.
- 4. Be patient and wait to plant discharge areas until salts leach from the planting zone.
- 5. Do not fallow if available water in the top 4 feet of soil is sufficient to grow a minimal crop, or if the soil texture is sandy loam or coarser.
- 6. Use long growing season, deep rooted crops to control the water table depth.

REFERENCES

- Bauer, A. and T. J. Conlon. 1978. Influence of tillage interval of fallow on soil water storage. N. Dak. Farm Res. Bull. 35(4):8-11.
- Black, A. L., P. L. Brown, A. D. Halverson and F. H. Siddoway. 1981. Dryland cropping strategies for efficient water use to control saline seeps in the Northern Great Plains. Agr. Water Mgt 4:295-311.
- Cassel, D. K. and M. D. Sweeney. 1974. In Situ soil water holding capacities of selected North Dakota soils. North Dakota Agricultural Experimentation Bulletin #495.
- Brun, L. J. and B. K Worcester. 1975. Soil water extraction by alfalfa. Agron. J. 67:586-588.
- Doering, E. J. and F. M. Sandoval. 1976. Saline seep development on upland sites in the Northern Great Plains. ARS-NC-32.
- Gismer, M. E. and T. K. Gates. 1988. Estimating saline water able contributions to crop water use. Calif. Agr. 42(2):23-24.
- Hoggard, T. J. and T. L. Henry. 1984. Comparison of 1:1 and 1:2 suspensions and extracts with the saturation extract in estimating salinity in Saskatchawan soils. Can. J. Soil Sci 64:669-704.
- Holm, H. M. 1979. Saskatchawan soil salinity progress report #3 Sask. Ag.
- Johnsgard, G. A. 1974. Salt affected problem soils in North Dakota. 3rd printing. N. Dak. St. Univ. Ext. Serv. Bull. #2.
- Maas, E. V. 1986. Salt tolerance of plants. Applied Agr. Res. 1:12-26.
- Maianu, A. 1983. Salt tolerance of hard red spring wheat. In: 1983 Crop Production Guide. North Dakota Agricultural Association. Fargo, ND.
- Maianu, A. 1984. Salt tolerance of soybeans in the Red River valley. In:1984 Crop Production Guide. North Dakota Agricultural Association. Fargo, ND.
- Maianu, A. and J. Lukach. 1985. Satt tolerance of barley. In:1985 Crop Production Guide. North Dakota Agricultural Association. Fargo, ND.
- Seelig, B. D. and J. L. Richardson. 1991. Salinity and sodicity in North Dakota soils. North Dakota State Univ. Extension Service Bulletin 57.
- Sommerfeldt, T. G. and E. Rapp. 1982. Management of saline soils. Communications Branch, Agric. Canada, Pub. 1624E.
- Steppuhn, H., D. Curtin and F. Selles. 1991. The role of salt tolerant crops in sustainable irrigated agriculture. In: Proceedings of IRDC-90. Water Res. Inst. Univ. of Lethbridge, Alb. Canada.





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You Can Make A Difference

Water Quality for Livestock and Poultry

by Fred Bergsrud, Extension Agricultural Engineer and James Linn, Extension Animal Scientist

MINNESOTA EXTENSION SERVICE

University of Minnesota

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Water Quality for Livestock and Poultry

An adequate and safe water supply is essential to the production of healthy livestock and poultry. Water that adversely affects the growth, reproduction, or productivity of livestock and poultry cannot be considered suitable. Farm water supplies, either surface or ground, should be protected against contamination from microorganisms, chemicals, and other pollutants. Finally, the water supply must not affect the acceptability or safety of any animal products for human consumption.

When water is suspected of causing health problems in livestock, veterinary assistance should be sought in order to determine the actual disease. Laboratory diagnostic examination of both animals and the water supply may be necessary to adequately evaluate the problem. Temporarily changing to a known safe water supply is a useful test to determine if the health problems can be solved. Remember, however, that water is too often blamed

for production or disease problems. Thus, the importance of an accurate diagnosis must be emphasized.

It is important to stress that the water quality recommendations in this publication pertain only to livestock and poultry, and not to human drinking water. Human drinking water standards are the responsibility of the U.S. Environmental Protection Agency. For more information on the human consumption of water, refer to Agricultural Extension Service Folder 547 Drinking Water Quality in Minnesota.

This folder will discuss those water quality factors that have been shown to cause livestock health or production problems and are likely to occur in Minnesota. Additional information about the effects of water quality on livestock and poultry is available from the faculty and departments listed at the end of this publication.

NITRATES

Sources and Movement of Nitrates in Water

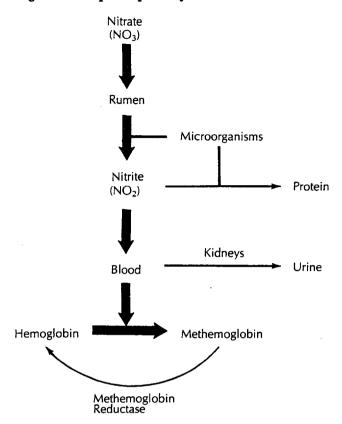
Nitrates are soluble and move with percolating water. Nitrates added to or produced within the soil profile may be washed away by surface runoff or leached to the ground water by percolation. Ground water pumped from a well may contain nitrates even if their source is a considerable distance from the well. Sources of nitrates in ground waters include nitrogen fertilizers, animal manure or wastes, crop residues, human wastes, and in some cases industrial wastes.

As nitrates percolate downward, they may reach a shallow ground water table. The nitrate concentration will be the greatest in the upper 5 feet of a shallow ground water table and wells which just penetrate into the table may remove water relatively high in nitrates. Waters from shallow wells normally contain more nitrates than waters from deeper wells because the shallow ground water table is easily polluted with leached nitrates.

While deep wells are usually nitrate free in Minnesota, an improperly located or improperly constructed deep well can be polluted with surface or ground water. Pollutants can enter deep aquifers through abandoned wells which have not been adequately sealed. A rusted or perforated well casing from an old well may allow ground water from a shallow contaminated formation to reach a deep aquifer. In some cases, old wells have been carelessly used for sewage or waste disposal allowing contaminants to enter directly into the ground water.

In the karst topography of southeastern Minnesota, sink holes allow direct contamination of fractured rock aquifers. Some of these aquifers have acquired relatively high nitrate levels. In some areas of Minnesota, particularly the southwest, relatively high levels of nitrate exist naturally in the ground water.

Figure 1. A simplified pathway for nitrates in ruminants.



How Nitrates Poison (Cattle, Goats and Sheep)

Nitrates by themselves are not very toxic. However, in the rumen of the cow or sheep, microorganisms change nitrates to nitrites, which are quite toxic (see **figure 1**).

Nitrites may be further acted upon by microorganisms converting nitrite-nitrogen into protein. In cows or sheep that consume large amounts of nitrates in short periods of time, however, nitrites accumulate faster than they can be built into protein. Note that water is only one source of nitrates for animals. Feedstuffs may contribute far more nitrates than those ingested by drinking water. For example, corn silage which is made during drought periods may be particularly high in nitrates.

From the animal's stomach, the excess nitrites are absorbed into the blood stream. While a small portion of the nitrites will be excreted in the urine, most of them will react with the hemoglobin (the red, oxygen-carrying pigment of the blood) to form methemoglobin, which precludes the blood from carrying oxygen (the blood turns chocolate brown). If a large portion of the hemoglobin has been

converted to methemoglobin, the animal shows symptoms of asphyxiation including labored breathing, a blue muzzle and a bluish tint to the whites of the eyes, trembling, lack of coordination, inability to stand, and often death. Animals that recover will, except as in instances as noted below, show no after effects. Milk from animals displaying symptoms of nitrate poisoning should not be consumed as it may contain nitrites. However, healthy animals consuming nitrates have not been found to have nitrites in milk they secrete. Recovery is usually quite rapid since the enzyme (methemoglobin reductase) which converts methemoglobin back to hemoglobin is present in the blood. Exception to complete recovery concerns pregnant animals that have received so near a fatal dose that the fetus they carry dies and is later aborted.

How Nitrates Poison (Swine, Poultry and Horses)

In the simple-stomached animals such as swine and poultry, there is no fermentation vat similar to the rumen to aid in the digestion of roughages and to change nitrate to nitrite. Some nitrites may be

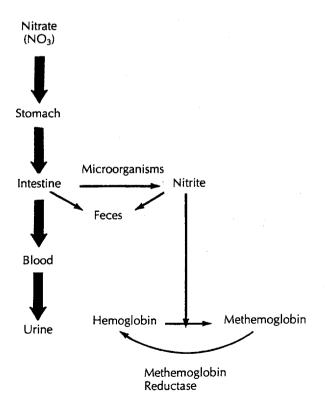


Figure 2. A simplified pathway for nitrates in swine and poultry.

formed in the intestinal tract (see figure 2), but this is so small an amount that it is of no consequence to animal health.

Most of the nitrates or nitrites pass unchanged from the intestines into the blood and then are eliminated by the kidneys. While nitrates themselves have some physiological effects, they are small when compared to those of nitrites, and it is unlikely that nitrites ever occur high enough naturally in water to harm swine and poultry. Horses are also simple stomached, but they have a large cecum (appendix), and this acts much like the rumen in digesting roughages. Nitrite formation can take place in the cecum, and horses are susceptible to nitrate poisoning because of this.

Dangerous Levels

At what level are nitrates in drinking water dangerous to livestock? A number of factors must be taken into account to arrive at such a value. These factors include the kind of animal, quantity of intake, the kind of feed, and the nitrate content of the feed. Taking these into account and allowing for a reasonable margin of safety, the guide shown in table 1 was developed by South Dakota State University staff based on published data and years of observation.

The National Academy of Science has found that livestock and poultry studied under controlled

experimental conditions can tolerate the continued ingestion of waters containing up to 300 ppm of nitrates or 100 ppm of nitrites. Their recommendation is, "in order to provide a reasonable margin of safety to allow for unusual situations...nitrates should be limited to 100 ppm or less and nitrite content alone be limited to 10 ppm or less."

Research results in southeastern Minnesota suggest that the South Dakota nitrate standards are probably relevant in Minnesota. Water supplies containing sufficient nitrate to cause livestock poisoning are seldom found in Minnesota. If a ground water supply is found to be high in nitrate, it is wise to test for the possible presence of coliform organisms.

It should be pointed out that there are a number of ways in which chemists have reported the nitrate contents of waters, and this has led to mistaken interpretations. Factors for converting other methods of reporting to a nitrate-nitrogen basis are shown in the footnotes for table 1.

It is also important to stress here that the recommendations in table 1 pertain only to livestock.

Nitrites in Water

Nitrites are occasionally found in water but usually only at very low levels. Rarely are they found at a concentration of over 1 or 2 ppm (part

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Nitrate content* as parts per million (ppm) of nitrate nitrogen (NO3N)+	Comments
Less than 100	Experimental evidence indicates this water should not harm livestock or poultry.
100 to 300	This water should not by itself harm livestock or poultry. If hays, forages or silages contain high levels of nitrate this water may contribute significantly to a nitrate problem in cattle, sheep, or horses.
Over 300	This water could cause typical nitrate poisoning in cattle, sheep, or horses, and its use for these animals is not recommended. Because this level of nitrate contributes to the salts content in a significant amount, the use of this water for swine or poultry should be avoided.

^{*} The values shown include nitrate nitrogen. In no case should the waters contain more than 50 ppm nitrite nitrogen (NO₂N) because of the greater toxicity of the nitrite form.

4.4 ppm of nitrate (NO.)

6.1 ppm of sodium nitrate (NaNO.)

7.2 ppm of potasium nitrate (KNO.)

I milliequivalent (mea) per liter of nitrate nitrogen is equivalent to 14 ppm.

^{+ 1} ppm of nitrate nitrogen is equivalent to:



Young stock in loose housing drink from common waters.

per million) of nitrite-nitrogen, and this amount is far below toxic levels for livestock and poultry. It is true that microbial growth in dirty troughs is able to change nitrate to nitrite, but the extent of this change has been found to be small. It has been suggested that the zinc in galvanized tanks or troughs causes nitrates to be changed to nitrites, but evidence for this is lacking and there is no sound theoretical basis for assuming that this conversion should happen. In short, nitrite amounts in most water supplies seem to offer no problems to livestock.

Chlorination

Chlorination of water does not destroy nitrates! Why then has chlorination been recommended by some as a remedy for high nitrate waters? The recommendation is likely based upon two facts: (1) that chlorine can convert nitrites back to nitrates,

and (2) that chlorine can kill microorganisms that might cause nitrates to be changed to nitrites, or that might form nitrates in the first place.

However, some additional facts must be considered to evaluate the chlorination recommendation. Since nitrites do not occur naturally at dangerous levels in water, chlorination is not necessary to change nitrites back to nitrates. While chlorination will destroy microorganisms, the introduction of filth or contaminants into the water at the waterer destroys the effectiveness of the chlorination. Chlorine will first oxidize the organic materials and insufficient chlorine concentration may remain to destroy microorganisms. In order for nitrites to be formed from nitrates in water troughs, organic matter must be present to provide for growth of the microorganisms.

In addition, chlorine in the drinking water cannot prevent the change of nitrates to nitrites in the rumen of the cow or sheep or the cecum of the horse unless the chlorine level is so high that it would cause physical damage to the animal.

Chlorination can be useful to control a nuisance bacteria population, such as iron bacteria, and along with a proper filter is also used to remove iron and odors from water. But chlorination by itself is not a remedy for high nitrate waters. Chlorination procedures are discussed in M-156 Chlorination of Private Water Supplies.

Solving the Problem

What can be done about water that contains nitrates at a concentration which makes it unsuitable for use by livestock?

Nitrates are not removed by filters, water softeners, additive softening compounds, and they are not destroyed by standing or boiling. They can be removed or reduced in concentration by some ion exchange resins, reverse osmosis, electrodialysis, or distillation. The cost of these practices may make them impractical for treating the volume of

water required for a livestock unit. Usually water unsuitable for farm animals because of its high nitrate content should be replaced by an uncontaminated source. A deeper water supply well may provide water which is low in nitrates. Well drilling techniques have been improved considerably since many of the older and shallower wells were constructed. Consult with a local well driller to determine if a deeper water bearing aquifer is likely to be present and inquire about the cost of the well.

Small ponds can be used for a farm water supply where a controlled watershed is available. The watershed should be of adequate size and should be protected against erosion, high applications of manure or chemicals, etc., in order to provide high quality water. If protective measures are taken and the watershed is controlled, a farm pond can deliver low nitrate water for a livestock enterprise. Surface water also is usually low in dissolved minerals. Consult with the Soil Conservation Service on technical assistance for the construction of a farm pond.

SULFATES

Sulfates are one of the dissolved solids that appear in Minnesota water and are usually either magnesium sulfate (Epsom salt) or calcium sulfate. Both of these salts will cause a cathartic (laxative) effect and Epsom salt is a commonly used laxative. These salts appear in the water because they have been dissolved as the recharge water moves down through soil and rock formations. Man's activities have little effect upon the concentration of sulfates in ground water supplies.

Problem Levels

The U. S. Public Health Service recommends that waters containing more than 250 ppm of chlorides or sulfates not be used for human consumption. Excessive concentrations of sulfates cause a laxative effect in animals, which is more pronounced in the young than the mature animal. In young animals, sulfate concentrations in excess of 350 to 600 ppm may be associated with severe, chronic diarrhea, electrolyte imbalance, and in a

few instances, death. Lactating dairy cattle will often have a lower milk fat percentage (.1 to .2 percentage units lower) when consuming water above 600 ppm in sulfate.

Solving the Problem

As with humans, animals tend to become acclimated to the sulfates in water. If a severe cathartic effect is experienced by newly purchased animals, they will likely become acclimated to the high sulfate water after a period of time. To reduce the cathartic effect, consider diluting the high sulfate water with water containing no sulfates. A dilution of three to four to one may be necessary to minimize the cathartic effect. Gradually increase the amount of high sulfate water in the mixture. This same procedure may be effective with young pigs at weaning time. This process requires additional management and a tank to haul and contain the water supply. However, this procedure is the most inexpensive method of reducing the

cathartic effect of high sulfate water.

If the animals do not become acclimated to the high sulfate water then sulfates will need to be removed from all of the water used by the livestock production unit. Techniques such as distillation, reverse osmosis, electrodialysis, and demineralization are all available but require relatively high levels of management and may not be economically feasible for the livestock producer.

The use of a home water softener does not

remove sulfates. The softener merely changes the magnesium or calcium sulfate into sodium sulfate which is somewhat more laxative.

Your local water well contractor may have information on aquifers at different depths which are likely to contain water low in sulfates. If water of suitable quality can be obtained from a new well, this would likely be the most cost effective solution to the problem. A small pond as explained in the section on nitrates, may provide low sulfate water.

TOTAL DISSOLVED SOLIDS

The term Total Dissolved Solids (TDS) includes all the minerals which have been dissolved as the recharge water percolates downward through the soil and rock formations. There is little that man's activities can do to change the amount of total dissolved solids in an aquifer.

Problem Levels

Most domestic animals can tolerate a total dissolved solid concentration in the range of 15,000 to 17,000 ppm. However, these concentrations will likely affect production. Some investigators have found that concentrations as high as 15,000 ppm are safe for a limited period but dangerous for continued use. Livestock specialists in Colorado and Montana classify water as good when it contains less than 2,500 ppm of dissolved solids. In South Dakota, the "good" water category extends to 4,000 ppm. The National Academy of Science recommendation is 3,000 ppm.

Australian agriculturists recommend safe upper limits according to species as follows:

Table 2. Upper Limit of TDS Concentrations

Animal	Threshold* TDS concentration, ppm
Poultry	2,860
Swine	4,290
forses	6,435
Cattle, dairy	7,150
Cattle, beef	10,000
Sheep, adult dry	12,900

^{*} Threshold: The point where a psysiological effect may be produced.

Salt water toxicity resembles the symptoms of simple dehydration and will upset the electrolyte balance. Levels over 10,000 ppm affect palatability for animals and, if consumed, will produce weight loss and diarrhea.

Solving the Problem

Total dissolved solids are difficult and expensive to remove from a water supply. The proposed solutions are the same as for sulfates.

MICROORGANISMS

Coliform bacteria are nearly everywhere and may be of plant, animal, or soil origin. The term fecal coliform bacteria refers to normal organisms found in the gastrointestinal tract of livestock, humans, and birds. While these bacteria may not be harmful, their presence often indicates that other disease-causing bacteria may also be present.

Harmful microorganisms can readily enter a

well having improper surface protection. Wells with cracked casings or wells situated so as to receive drainage from a feed lot or a well pit may result in bacteria to entering the water supply. Bacteria such as Salmonellas can cause disease, especially in young animals, and also can indirectly get into the milk supply from dairy herds. Although waterborne illness in livestock due to

microorganisms is not often reported in Minnesota, the potential exists for problems to occur, especially where large concentrated animal populations exist and where wells are poorly protected from surface run-off as experienced during spring and with heavy rainfall.

There are no legal limits for microorganisms or chemicals in water used for livestock production except if the farm is a dairy operation. In this case, the water must be from a supply which has been microbiologically tested safe by an approved water testing laboratory before milk can be sold from that farm. Grade A dairy farm water supplies must meet the Minnesota Water Well Construction Code established by the Department of Health which requires testing every three years or any time repairs or modifications are made on the water supply system. Manufacturing Grade dairy farms must have their water supply tested safe each year if their well does not meet the Minnesota Water Well Construction Code.

It is possible that microorganisms can contaminate a water supply at the drinking point. Bacteria and other organisms can develop rapidly in the waterers for turkeys and chickens raised under floor and range production systems.



Healthy horses require an adequate supply of high-quality water at all times.

Nipple-type waterers minimize the chances of a sick animal infecting others. With no standing water present, bacterial numbers will usually be insufficient to cause infection.



Occasionally, a water tank is located directly under the ventilation exhaust from a livestock building in order to provide a heat source to keep the water from freezing. Consider, however, that the water surface will be directly exposed to microorganisms which are carried out of the structure with the exhausted air. Thus, the watering tank could serve as a source of contamination by water even though the remainder of the water supply system is free of microorganisms. The exhausted air may contain microorganisms and also serve as a source of infection when an animal is drinking from a water tank located near an exhaust fan.

Solving the Problem

If the water test results indicate the presence of coliform organisms, the water supply system should be checked to determine possible sources of entry. The most common sources for entry of coliform organisms into a water supply are near the immediate area of the well itself or into the water storage container, such as a cistern.

Cisterns are usually masonry which is susceptible to cracking. Thus, microorganisms can enter the cistern as the liquid level goes up and down.

Dug wells commonly have a very poor surface cover and are inadequately protected against the direct entrance of coliform organisms from small



A recommended daily procedure is to thoroughly scrub and rinse poultry waterers with a disinfectant.

animals or from surface run-off which accumulates in the vicinity of the well. Drilled wells which terminate in a well pit are also commonly contaminated by drainage into the pit. If the well is drilled and cased, a pitless underground discharge can be used to replace the well pit. The well pit should be filled with a compacted loam or clay soil and all surface water should be directed away from the well location.

The first requirement of a water supply well is to deliver water free of coliform organisms. It is not sound practice to use chlorine to keep a continuing supply of pathogens in a contaminated well under control. Any failure of the chlorination equipment will immediately expose the livestock and poultry to the pathogens. If the source of contamination in a well cannot be eliminated, the only recourse may be to drill a new well.

Where the possibility exists that animals can transfer pathogens at the drinking point, a chlorine residual of 5 ppm may be helpful. However, in order for the chlorine residual to remain and destroy whatever microorganisms may enter the water, the watering device must be kept clean.

Troughs should be sited and elevated such that contamination for fecal material is virtually impossible. The "nipple-type" waterer helps to eliminate a source of water contamination between animals. Do not locate an outside water tank directly under a ventilation exhaust fan.

Proper cleaning of poultry waterers on a daily basis is an important part of flock management. A recommended procedure is to scrub water pans or troughs thoroughly with a brush, empty, and then rinse with a disinfectant. Studies have shown that bacteria counts in waterers properly cleaned daily can be kept relatively low. Poor practices in cleaning waterers can result in subjecting birds to water containing millions of bacteria per milliliter.

IRON

According to Report No. 26 of the Council for Agricultural Science and Technology, "Under usual conditions, water supplies only a small percentage of the iron available to animals. Because iron from natural sources is absorbed with efficiency less than 10%, the iron in water should not pose a hazard to animals. Under these circumstances, a 'no limit' recommendation is reasonable. High doses of the more available forms of iron, however, are toxic."

There is no evidence to show that iron will cause any problems with livestock or poultry products. An exception might be the so-called "white veal" trade which tries to develop a pale product based on milk, darkness, and a diet low in iron.

Solving the Problem

Iron can be removed from drinking water with a water softener or with an iron filter. Iron problems and removal techniques are discussed in M-154 Iron in Drinking Water.

PESTICIDES

Pesticides can enter a groundwater or surface water supply from run-off, drift, rainfall, direct application, accidental spills (immediately notify the Minnesota Department of Agriculture, or call the statewide 24 hour emergency number for the duty officer from the Emergency Management Division, Minnesota Department of Public Safety (non-metro—1-800-424-0798, metro—1612-649-5451)), faulty storage facilities, and faulty waste disposal techniques. Pesticides should be used only when necessary. When pesticides are used all label directions should be strictly followed, together with approved application techniques. The Minnesota Extension Service provides pesticide applicator's training.

There have been no reported cases of domestic livestock deaths resulting from pesticides contained in livestock drinking water. Many pesticides are readily broken down and eliminated by livestock with no obvious ill effects, but there is a possibility that some could be excreted in milk or accumulate in meat. Of the pesticides currently in use, the organophosphates are the most dangerous for livestock. It should be noted that fish are much more sensitive to pesticides than are livestock or poultry.

The National Academy of Sciences recommends that "the maximum levels for public water supplies for individual pesticides are recommended for farm animal water supplies." In Minnesota, pesticide levels in ground and surface waters have not been shown to be a problem for livestock production.

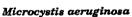
Solving the Problem

It is extremely difficult and expensive to test for unknown pesticides or suspected chemicals in water. If the chemical can be identified, a test can be performed to determine if that chemical is present in the water supply. If a general chemical pollution is suspected, it will be extremely expensive to determine which pesticide or which chemicals may be present in the water.

The best solution is to prevent the problem from occurring. Be sure that there is adequate drainage around any water supply well. The well should be located on elevated ground where surface run-off will not reach the well.

If a surface water supply which as an excavated pond or impoundment is used, the design should include waterways which prevent uncontrolled surface runoff from entering the water supply.







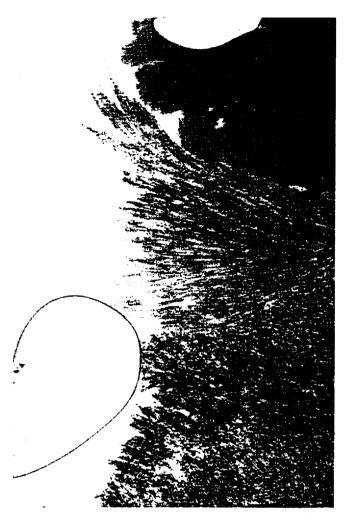
Anabena flos-aquae

BLUE-GREEN ALGAE

For over 100 years, toxic blue-green algae or toxic water blooms have been recognized as a problem in Minnesota, particularly in the relatively shallow lakes of southern and central Minnesota. Algae grow and multiply because of favorable nutrient and temperature conditions. Water with a high level of algal nutrients will experience algal blooms with lower water temperatures than less nutritious water. Surface waters and ponds will have algal blooms whenever nutrient and temperature conditions are favorable. Algal blooms occur in Minnesota between May and early November; their growth is favored by hot, dry weather, usually in mid-summer. Wind causes the algae to accumulate along the downwind shores of lakes, ponds, and streams. Algal blooms can appear almost overnight, continue for several days to a week,

and then rapidly recede with the advent of cooler weather and rain. Some lakes or ponds frequently have several algal blooms during a summer. Farm ponds and stock tanks can also be affected.

The three different types of toxic blue-green algae found in Minnesota are Microcystis aeruginosa, Anabena flos-aquae, and Aphanizomenon flos-aquae. The first two are most commonly encountered and are quite readily identified by microscopic examination of the water. Blue-green algae poisoning is quite common in grazing livestock causing muscle tremors, diarrhea, lack of coordination, collapse, labored breathing, liver damage and death. Effects can occur from within a few minutes to a day, and animals that recover often shed large sections of the unpigmented (white) areas of their hides. All species are affected.



Aphanizomenon flos-aquae

Other Water Borne Problems

Botulism affects livestock, dogs and birds especially waterfowl. The organisms, Clostridium botulinum is found in most soils but especially in lakes when high temperatures and receding shorelines

result in conditions conducive for their multiplication. Signs in cattle include loss of appetite, severe depression, and reduced milk yield, while in birds, neck paralysis is the major sign. Alaboratory diagnosis is necessary to confirm the disease. Vaccination, dispersal of animals and birds and provision of alternate water supplies are options for prevention.

Leptospirosis. This disease is caused by Leptospira bacteria which thrive in moist areas and surface water. Livestock exposed to these organisms may pass red urine, abort, or show a sudden drop in milk production. Vaccines are available to prevent leptospirosis.

Solving the Problem

Water containing a bloom of blue-green algae should not be used for watering livestock. There is no specific antidote to algae poisoning. The best thing to do is administer large quantities of medicinal-grade charcoal and mineral oil. Animals must be denied access to the algae-contaminated water and provided with a supply of suitable water.

Algae can be controlled with copper sulfate in concentrations of about 1.0 ppm. This is equivalent to 3 pounds of copper sulfate per acre-foot of water. To keep algae under control several applications may need to be made to a body of water during a summer. It is recommended that livestock not drink the treated water. Also remember that algal blooms can occur in a very short period of time and it may be extremely difficult to control all blooms in a body of water that is high in algal nutrients.

Algal blooms can also occur in stock tanks if nutrients and temperature conditions are favorable. Periodically cleaning the stock tank to remove the nutrient source is the best way of preventing algal blooms there. In real problem situations, adding 3 ounces of chlorine bleach for every 50 gallons every 10 to 14 days will help control algal bloom in stock tanks.

OTHER FACTORS

Stray Voltage

This problem has been more widely identified and is steadily increasing on Minnesota dairy farms. If stray voltage is a problem, animals may curtail their water intake resulting in production losses. Water consumption problems which are related to stray voltage may be incorrectly interpreted as a water quality problem. A complete discussion of the stray voltage problem is presented in AG-BU-1359, Stray Voltage Problems with Dairy Cows.

Water Temperature

There is little evidence to show that livestock production is affected by drinking water temperature in the range from above freezing to summer ambient temperatures. Lactating dairy cows have been shown to produce the most milk when offered water between 50 and 65 degrees F. Water temperature above 75

degrees F decreases water intake and milk production. Poultry have been shown to decrease their intake of water when the water is warm, especially in hot weather. Warm water also is subject to more bacterial growth than cold water.

WATER TESTING

Contact your community or county health service, county extension agent or veterinarian for information where water samples can be examined and what tests may be required. Remember that tests for microorganisms require that the water faucet run for several minutes before the sample is collected in a sterile container, sealed, and dispatched to the testing laboratory to arrive within 24 hours. It is recommended that tests be made by laboratories that have been approved by the Minnesota Department of Health.

If the results of water tests indicate that problems may exist, field officers of the Minnesota Department of Health Well Managementl Unit are available for advice and recommendations by contacting the main office at 717 Delaware Street SE, Minneapolis, MN 55440. District offices of the Minnesota Department of Health are located at Bemidji, Duluth, Fergus Falls, Sauk Rapids, Marshall, Mankato, and Rochester.

OBTAINING A NEW WATER SOURCE

If it is determined that an existing water supply is either unsatisfactory in terms of chemical or microbial contamination, or if the supply is inadequate for the existing or expanding livestock operation, a new well may have to be drilled. The services of a licensed water well contractor should be obtained and the well should be constructed according to the provisions of

the Minnesota Water Well Construction Code. Further information on water well construction can be obtained from the Well Management Unit, Division of Environmental Health, Minnesota Department of Health, 717 Delaware Street SE, Minneapolis, MN 55440. The district offices listed above also have water source information.

ADDITIONAL SOURCES OF INFORMATION

The following faculty of the University of Minnesota have contributed to this publication and may be contacted through your local county extension office for additional information:

Veterinary Medicine Veterinary Medicine Dairy Cattle Beef Swine Horses and Sheep Poultry Dr. Ashley Robinson
Dr. Larry Stowe
Dr. James Linn
Dr. Jay Meiske
Dr. Jerry Hawton
Dr. Robert Jordan
Dr. Mel Hamre

WATER QUALITY GUIDELINES FOR BEEF AND DAIRY CATTLE

Water is the nutrient required in the largest quantity by beef and dairy cattle. Daily intakes of water can range from 5% of body weight for a beef cow to 20% of body weight for a high producing dairy cow. A lack of water intake will have a rapid and dramatic effect on animal health and productivity. The following guidelines are based on limited research and field observations, and are not standards. They are presented as an aid in evaluating water quality tests and trouble shooting water intake problems on farms.

WATER ANALYSIS	ACCEPTABLE				
pH	6.0-8.0				
Total Dissolved Solids (TDs)	0-3000 ppm				
Hardness	Generally no problem				
Nitrate nitrogen	0-100 ppm				
Nitrite nitrogen	0-10 ppm				
Sulfate	0-500 ppm				
Lead	01 ppm				
Mercury	001 ppm				
Total bacteria	0-1000/ml				
Coliform bacteria	0-50/100 ml				

General conversions

ppm = parts per million

10,000 ppm = 1%

1 ppm = 1 milligram/liter (mg/1) or 1 milligram/1000 milliliters

1 grain/gallon = 17.1 ppm or 17.1 mg/1

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Appendix H

Information Summaries Non-Permitted Users

Interview#: 1 Reach/River: Upper Sheyenne River

Use: Cattle and recreation **Acres**: N/A **Intake location**: unknown

Crop types: N/A Quantity/Rate/Time of Year: unknown

quantity; all year round

May 1998—Interviewee uses an unknown quantity of water from the Sheyenne River all year 'round for cattle and recreation. He is satisfied with the water quality of the river. He said that if water quality were to change, he would need an alternative source of water for the cattle in two pastures; the house wells are too shallow (25 feet) and he would need to consider drilling new wells for the cattle and possibly the house. Interviewee was unable to quantify costs associated with these changes. [txc]

Interview#: 2 **Reach/River**: Upper Sheyenne River

Use: cattle water (feedlot) Acres: N/A Intake location: unknown

Crop types: N/A **Quantity/Rate/Time of Year**: unknown

quantity; when river is open

May 1998—Interviewee uses an unknown quantity of water from the open Sheyenne River for a large amount of cattle. He operates a feedlot and is satisfied with the quality of the river. If the quality were to change, interviewee said he would have to prevent the cattle from drinking from the river and would need an alternative source of water. The feedlot is too large to supply water for without the use of the river. [txc]

Interview#: 3 **Reach/River**: Upper Sheyenne River

Use: garden watering **Acres**: minimal **Intake location**: see Sverdrup in Griggs Co.

plat book

Crop types: flowers and vegetables **Quantity/Rate/Time of Year**: unknown

quantity; summer

May 1998—Interviewee uses water from the Sheyenne River for his garden, which includes flowers and vegetables. An unknown amount of water is taken from the river during the summer months. Interviewee is currently satisfied with the quality of water he is using and does not foresee any effects that a change in water quality would have on his garden. [txc]

Interview#: 4 Reach/River: Upper Sheyenne River

Use: lawn and cattle watering **Acres**: minimal **Intake location**: see Nesheim in

Nelson Co. plat book

Crop types: N/A **Quantity/Rate/Time of Year**: rarely;

in summer

May 1998—Interviewee has, on rare occasions during summer months, used water from Sheyenne River to water his lawn and give to his cattle. He was satisfied with the quality of water and could not foresee any effects that a change in water quality would have on his lawn or cattle. [txc]

Interview#: 5 Reach/River: Upper Sheyenne River

Use: cattle water **Acres**: N/A **Intake location**: see Nesheim in Nelson Co. plat

book

Crop types: N/A **Quantity/Rate/Time of Year**: unknown quantity;

spring, summer, and fall

May 1998—Interviewee uses the Sheyenne River as a source of cattle water during the spring, summer, and fall. He is currently satisfied with the water, but said that if water quality were to change, he would need a new source. Interviewee would consider using well water and he estimated the cost of a new well to be approximately \$500. [txc]

Interview#: 6 Reach/River: Lake Ashtabula

Use: watering **Acres**: minimal **Intake location**: approx. 5 miles north of dam

Crop types: garden and lawn **Quantity/Rate/Time of Year**: summer use as

needed

June 3, 1998—Interviewee said she uses water from Lake Ashtabula to water her lawn and garden (peas, corn, tomatoes, etc.). She uses it on an as-needed basis during the summer. Interviewee is not satisfied with the water quality of the lake and is very concerned about the water's effects, primarily on fish. If the water quality were to get worse, interviewee would stop using water from the lake and would use rural water (already connected). However, she says that water is very expensive (approximately \$264 a year plus an additional cost per gallon). [sas]

Interview#: 7 Reach/River: Lake Ashtabula

Use: watering **Acres**: minimal **Intake location**: unknown

Crop types: garden, lawn, and trees **Quantity/Rate/Time of Year**: unknown quantity;

as needed during summer

June 3, 1998—Interviewee uses water from Lake Ashtabula to water his lawn, garden, and trees during the summer on an as-needed basis. He is satisfied with the quality of the water. If the quality were to drop, interviewee would consider taking water from a creek before it entered the lake or using rural water (already connected). There would be an additional cost per gallon If interviewee used rural water. [sas]

Interview#: 8 Reach/River: Lake Ashtabula

Use: watering **Acres**: minimal **Intake location**: see plat map

Crop types: garden and lawn **Quantity/Rate/Time of Year**: unknown quantity;

summer

May 1998—Interviewee uses water from Lake Ashtabula for his lawn and garden. An unknown amount of water is taken from the lake during the summer months. Interviewee is currently satisfied with the quality of water he is using and does not foresee any effects that a change in water quality would have on his lawn and garden. [txc]

Interview#: 9 Reach/River: Lake Ashtabula

Use: fill pool, recreation **Acres**: N/A **Intake location**: see Ashtabula in Barnes

Co. plat book

Crop types: N/A Quantity/Rate/Time of Year: unknown

quantity; summer

May 1998—Interviewee uses an unknown quantity of water from Lake Ashtabula during the summer months to fill the camp's pool. The camp also uses the lake for canoeing and recreation. Interviewee is currently satisfied with the water quality, but said that a change is water quality could affect the camp by changing wildlife and recreation on the lake. He suggested not pumping water from Devils Lake into the Sheyenne River. [txc]

Interview#: 10 **Reach/River**: Lake Ashtabula

Use: cattle and sheep water **Acres**: N/A **Intake location**: see Ashtabula in Barnes

Co. plat book

Crop types: N/A **Quantity/Rate/Time of Year**: unknown

quantity; summer

May 1998—Interviewee uses an unknown quantity of water from Lake Ashtabula during the summer for his cattle and sheep. He is currently satisfied with the water quality, and doesn't know what kind of effects a change in quality would have on his livestock. He does have a backup well. [txc]

Interview#: 11 Reach/River: Lower Sheyenne River

Use: garden/lawn Acres: minimal Intake location: unknown

Crop types: N/A **Quantity/Rate/Time of Year**: unknown quantity;

summer

May 1998—Interviewee uses an unknown quantity of water from the Sheyenne River during the summer for his garden and lawn watering. He is currently satisfied with the water quality, but said he would need to find another source of water if quality were to change. One alternative that interviewee would consider would be digging a well. [txc]

Interview#: 12 **Reach/River**: Lower Sheyenne River

Use: cattle water **Acres:** N/A **Intake location:** see Nelson in Barnes Co. plat

book

Crop types: N/A **Quantity/Rate/Time of Year**: unknown quantity;

all year but winter

May 1998—Interviewee uses an unknown quantity of water from the Sheyenne River during the spring, summer, and fall for cattle. She is currently satisfied with the water quality of the river, but said she would need to use an alternative source of water should the quality drop. Interviewee said she currently has a backup well, so there would be no additional cost for her should she need to change sources. [txc]

 Interview#: 13
 Reach/River: Lower Sheyenne River

 Use: garden/lawn watering
 Acres: minimal book
 Intake location: see Marsh in Barnes Co. plat book

 Crop types: N/A
 Quantity/Rate/Time of Year: unknown quantity; summer

May 1998—Interviewee uses an unknown quantity of water during the summer months on his garden and lawn through an underground sprinkling system. He is currently satisfied with the water quality of the river and is unsure of what effects a change in quality would have on his garden and lawn. He said that if the water became unsuitable for his garden, he would consider installing a well. [txc]

 Interview#: 14
 Reach/River: Lower Sheyenne River

 Use: cattle, garden, lawn
 Acres: minimal book
 Intake location: see Oak Hill in Barnes Co. plat book

 Crop types: N/A
 Quantity/Rate/Time of Year: unknown quantity; summer

May 1998—Interviewee uses an unknown quantity of water from the Sheyenne River during the summer for cattle and his lawn and garden. He is satisfied with the water quality of the Sheyenne River and does not expect harmful effects if the quality changes. [txc]

Interview#: 15

Use: lawn
Acres: minimal
Crop types: N/A

Quantity/Rate/Time of Year: unknown quantity; spring/summer

May 1998—Interviewee uses an unknown quantity of water from the Sheyenne River during the spring and summer to water his lawn. He is satisfied with the water quality of the river and does not expect any harmful effects if the water quality changes. [txc]

Interview#: 16 Reach/River: Red River Rural

Use: cattle **Acres**: N/A **Intake location**: see Wiser in Cass Co. plat book

Crop types: N/A **Quantity/Rate/Time of Year**: unknown quantity;

summer

May 1998—Interviewee uses an unknown quantity of water from the Red River during the summer to give his cattle. He is satisfied with the water quality and does not foresee any adverse effects from a possible change in quality. [txc]

Interview#: 17 Reach/River: Red River Rural

Use: Domestic **Acres**: N/A **Intake location**: see Big Woods in Marshall Co.

plat book

Crop types: N/A **Quantity/Rate/Time of Year**: unknown quantity;

summer

May & July 1998—Interviewee said that water from the Red River "leaks" into his cistern during the wet summer months. He currently is not very satisfied with the quality of the water in his cistern. Interviewee says if the river's water quality changed, it would affect the cistern water and he would have to hook up to rural water, which he says would cost approximately \$8,000 over many years. Interviewee was recontacted to determine specific water use. He reports that the water is used for everything in the house, including washing, drinking, etc. He also voiced concerns about the added flow the outlet may produce. [txc & sas]

Interview#: 18 Reach/River: Red River Rural

Use: Irrigation **Acres**: 1.5 **Intake location**: RL 31 & 32 (parish of St. Andrews)

Crop types: strawberries (3,000 **Quantity/Rate/Time of Year**: 4" pump used 1 week

plants) between May and July

May 19, 1998—Interviewee uses water from the Red River to irrigate 1.5 acres of strawberry crops (approximately 3,000 plants). Water is pumped near RL 31 and 32 at the parish of St. Andrews. Interviewee has a 4-inch pump that he uses to irrigate his strawberries for approximately one week between May and July. When the lock opens upstream, it floods the area, so interviewee can't use the water. Interviewee is currently satisfied with the quality of the water when he is actually able to use it. Effects of a change in water quality would depend on the type of change; for example, 10 or 15 years ago, phosphates caused problems. Interviewee also said that salt is not good for his crops. He estimated he could lose between \$5,000 and \$6,000 if his crops were damaged. According to interviewee, the only alternative to river water would be a well. He said a well would cost "a lot" and that he would not be able to afford a 6-inch well. [syh]

Interview#: 19 Reach/River: Red River

Use: Irrigation **Acres:** 40 **Intake location:** 12 miles south of Winnipeg on

Hwy. 200

Crop types: tomatoes, peppers, cucumbers, **Quantity/Rate/Time of Year**: dry= 6" over 40

onions, etc acres/season; wet= 1"/40 acres

May 29, 1998—Interviewee uses water from the Red River to irrigate 40 acres of vegetable crops. Water for his crops is withdrawn from the river approximately 12 miles south of Winnipeg on Hwy. 200. In a dry year, interviewee uses approximately 6 inches of water over 40 acres from June to September; in a wet year, 1 inch. He is satisfied with the quality of the water of the Red River. Interviewee says salt would kill his plants, and that he would lose \$100,000 to \$150,000 in net income. He said he would blame the government for his losses and seek compensation (i.e., he would sue the government). [txc]

Interview#: 20 Reach/River: Red River Rural

Use: Irrigation **Acres**: 90 **Intake location**: St. Norbert, Manitoba: Lot 40 &

41 (Ri Shot town), Hwy. 75

Crop types: trees/shrubs **Quantity/Rate/Time of Year**: unknown quantity,

early spring through fall

May 29, 1998—Interviewee, a nursery representative, uses water from the Red River to irrigate 90 acres of trees and shrubs during the spring, summer, and fall. The nursery takes water from the river at Lot 40 & 41 (Ri Shot town), Hwy. 75. Interviewee says a change in water quality would adversely affect his trees and shrubs; iron would be tied up in the soil and the leaves of his plants would turn yellow. Interviewee does not foresee any solutions to the problem. He said he would build dikes around his buildings (50 feet wide, 10 feet high) to protect them from flooding. [txc]

Interview#: 21 Reach/River: Red River Urban

Use: watering **Acres:** minimal **Intake location:** 405 George St., Drayton, ND

Crop types: garden and lawn **Quantity/Rate/Time of Year**: unknown quantity

May 29, 1998—Interviewee uses water from the Red River to water his lawn and garden. He is satisfied with the quality of water; if it were to change, he would not use it to water his garden and lawn. He doesn't foresee any other options of getting water. Interviewee is also concerned about flooding; he thinks there is too much water already. [txc]

Interview#: 22 Reach/River: Red River Urban

Use: Domestic **Acres**: N/A **Intake location**: 80 Kenabeek St., West St. Paul, MB

Crop types: N/A **Quantity/Rate/Time of Year**: unknown quantity/

Year round

July 17, 1998— Interviewee currently uses the water from the Red River as their primary drinking water source. They have a treatment system and therefore feel a change in water quality would not affect them. They pump the water from a well located approximately 100 feet from the river. They know that the river water is pumped from the river into the well. [txc]

Interview#: 23 Reach/River: Red River Urban

Use: watering **Acres:** minimal **Intake location:** 19 Everette Pl., West St. Paul, MB

Crop types: garden and lawn **Quantity/Rate/Time of Year**: Quantity varies/

Summer

July 17, 1998 — Interviewee currently uses the water from the Red River for lawn and garden watering. The amount of water used varies depending on weather conditions. She feels a change in water quality would not effect them because they have an existing well that could be used as an alternative water source. [txc]

Interview#: 24 Reach/River: Red River Urban

Use: watering **Acres:** minimal **Intake location:** 12 Baldock St., West St. Paul, MB

Crop types: garden and lawn **Quantity/Rate/Time of Year**: Quantity varies/

Summer

July 17, 1998 —Interviewee currently uses the water from the Red River for lawn and garden watering. The amount of water used varies depending on weather conditions (how dry). She is currently satisfied with the water quality of the Red River. She is not sure how a change in water quality would effect her but she has an existing well that could be used as an alternative water source. [txc]

Interview#: 25Reach/River: Red River UrbanUse: wateringAcres: minimalIntake location: 22 Everette Pl., West St. Paul, MB

Crop types: garden and lawn **Quantity/Rate/Time of Year**: Quantity varies/

Summer

July 17, 1998 — Interviewee currently uses the water from the Red River for lawn and garden watering. The amount of water used varies depending on weather conditions. He is currently satisfied with the water quality of the Red River. He is not sure how a change in water quality would effect his use but he has an existing well that could be used as an alternative water source. [txc]

Appendix I

Phase I Present Worth and Annualized Costs, by Trace and Treatment Facility

Table I-1 Municipal Water Treatment Facility Phase I (Softening) Costs Trace 6

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars, Annualized over 50 Years)
Valley City	\$129,174	\$9,508
Fargo	\$63,003	\$4,637
Grand Forks	\$241,757	\$17,795
Grafton	\$13,795	\$1,015
Drayton	\$8,244	\$607
Pembina	\$1,265	\$93
Morris	\$10,588	\$779
Letellier	\$20,951	\$1,542
TOTAL	\$488,779	\$35,978

Table I-2
Municipal Water Treatment Facility
Phase I (Softening) Costs
Trace 10

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars, Annualized over 50 Years)
)	
Valley City	\$127,548	\$9,388
Fargo	\$58,682	\$4,319
Grand Forks	\$172,587	\$12,704
Grafton	\$6,820	\$502
Drayton	\$4,539	\$334
Pembina	\$684	\$50
Morris	\$6,445	\$474
Letellier	\$12,264	\$903
TOTAL	\$389,569	\$28,675

Table I-3 Municipal Water Treatment Facility Phase I (Softening) Costs Trace 498

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars, Annualized over 50 Years)
Valley City	\$185,597	\$13,661
Fargo	\$89,170	\$6,564
Grand Forks	\$410,270	\$30,199
Grafton	\$20,100	\$1,480
Drayton	\$12,368	\$910
Pembina	\$2,157	\$159
Morris	\$17,894	\$1,317
Letellier	\$26,970	\$1,985
TOTAL	\$764,527	\$56,275

Table I-4 Municipal Water Treatment Facility Phase I (Softening) Costs Trace 2848

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars, Annualized over 50 Years)
Valley City	\$159,941	\$11,773
Fargo	\$83,853	\$6,172
Grand Forks	\$383,187	\$28,205
Grafton	\$20,395	\$1,501
Drayton	\$12,844	\$945
Pembina	\$2,232	\$164
Morris	\$18,010	\$1,326
Letellier	\$29,501	\$2,171
TOTAL	\$709,963	\$52,258

Table I-5
Municipal Water Treatment Facility
Phase I (Softening) Costs
Trace 6262

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars, Annualized over 50 Years)
Valley City	\$170,693	\$12,564
Fargo	\$84,764	\$6,239
Grand Forks	\$321,093	\$23,635
Grafton	\$16,371	\$1,205
Drayton	\$9,727	\$716
Pembina	\$1,460	\$107
Morris	\$12,112	\$892
Letellier	\$20,923	\$1,540
TOTAL	\$637,143	\$46,898

Table I-6 Municipal Water Treatment Facility Phase I (Softening) Costs Trace 6600

	Present Worth Cost	Annualized Cost
	for Treatment to Without-Outlet	for Treatment to Without-Outlet
Municipal Water	Concentrations of Total Hardness	Concentrations of Total Hardness
Treatment Facility	(1998 Dollars)	(1998 Dollars, Annualized over 50 Years)
Valley City	\$105,109	\$7,737
Fargo	\$50,636	
Grand Forks	\$152,679	\$11,238
Grafton	\$6,378	\$469
Drayton	\$4,453	\$328
Pembina	\$681	\$50
Morris	\$4,889	\$360
Letellier	\$11,137	\$820
TOTAL	#205.004	#04.700
TOTAL	\$335,961	\$24,729

Table I-7 Municipal Water Treatment Facility Phase I (Softening) Costs Trace 7352

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness (1998 Dollars, Annualized over 50 Years)
Valley City	\$126,068	\$9,280
Fargo	\$61,483	\$4,526
Grand Forks	\$219,969	\$16,191
Grafton	\$10,091	\$743
Drayton	\$7,076	\$521
Pembina	\$1,082	\$80
Morris	\$8,776	\$646
Letellier	\$14,369	\$1,058
TOTAL	\$448,914	\$33,043

Appendix J

Phase II Present Worth and Annualized Costs, by Trace and Treatment Facility

Table J-1

Municipal Water Treatment Facility

Phase II (Softening plus Additional Treatment) Costs

Trace 6

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars, Annualized over 50 Years)	Least Expensive Technology for Treatment to Reach Water Quality Objective*
Valley City	\$5,540,327	\$407,807	Well
Fargo	\$8,588,240	\$632,155	Ion Exchange
Grand Forks	\$13,000,963	\$956,963	Ion Exchange
Grafton	\$535,933	\$39,448	Treatment of Park River
Drayton	\$534,469	\$39,341	Ion Exchange
Pembina	\$262,071		Ion Exchange
Morris	\$1,715,177		Ion Exchange
etellier	\$2,158,628		Ion Exchange
TOTAL	\$32,335,809	\$2,380,145	

^{*}Notes: Ion Exchange refers to the treatment of the existing water source to without-outlet concentrations of total hardness and TDS.

Well refers to the installation of groundwater wells and the treatment of the water, if appropriate, to without-outlet concentrations of total hardness and TDS.

Rural Water refers to the connection to the rural water system and the treatment of the water, if appropriate, to without-outlet concentrations of total hardness and TDS.

Treatment of Park River refers to using the Park River as the primary water source and the treatment of the water to without-outlet concentrations of total hardness and TDS.

The water quality objective is to treat the water source to without-outlet concentrations of total hardness and TDS.

Table J-2
Municipal Water Treatment Facility
Phase II (Softening plus Additional Treatment) Costs
Trace 10

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars, Annualized over 50 Years)	Least Expensive Technology for Treatment to Reach Water Quality Objective*
Valley City	\$5,540,327	\$407,807	Well
Fargo	\$7,727,524		Ion Exchange
Grand Forks	\$9,362,195	\$689,124	Ion Exchange
Grafton	\$530,438	\$39,044	Treatment of Park River
Drayton	\$347,617	\$25,587	Ion Exchange
Pembina	\$196,508	\$14,464	Ion Exchange
Morris	\$1,064,347	\$78,343	ion Exchange
Letellier	\$1,331,705	\$98,023	Ion Exchange
TOTAL	\$26,100,661	\$1,921,194	

^{*}Notes: Ion Exchange refers to the treatment of the existing water source to without-outlet concentrations of total hardness and TDS.

Table J-3

Municipal Water Treatment Facility

Phase II (Softening plus Additional Treatment) Costs

Trace 498

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars, Annualized over 50 Years)	Least Expensive Technology for Treatment to Reach Water Quality Objective*
Valley City	\$5,540,327	\$407,807	Well
Fargo	\$11,355,764		Ion Exchange
Grand Forks	\$21,024,950	\$1,547,586	Ion Exchange
Grafton	\$541,964	\$39,892	Treatment of Park River
Drayton	\$688,583	\$50,685	Ion Exchange
Pembina	\$332,764	\$24,494	Ion Exchange
Morris	\$2,362,590	\$173,903	Ion Exchange
Letellier	\$3,039,735		Ion Exchange
TOTAL	\$44,886,677	\$3,303,978	

^{*}Notes: Ion Exchange refers to the treatment of the existing water source to without-outlet concentrations of total hardness and TDS.

Table J-4

Municipal Water Treatment Facility

Phase II (Softening plus Additional Treatment) Costs

Trace 2848

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars, Annualized over 50 Years)	Least Expensive Technology for Treatment to Reach Water Quality Objective*
Valley City	\$5,540,327	\$407,807	Well
Fargo	\$10,500,300		Ion Exchange
Grand Forks	\$19,513,520	\$1,436,334	Ion Exchange
Grafton	\$530,143	\$39,022	Treatment of Park River
Drayton	\$735,906		Ion Exchange
Pembina	\$343,339		Ion Exchange
Morris	\$2,474,894		Ion Exchange
Letellier	\$3,175,416		lon Exchange
TOTAL	\$42,813,845	\$3,151,403	

*Notes: Ion Exchange refers to the treatment of the existing water source to without-outlet concentrations of total hardness and TDS.

Table J-5
Municipal Water Treatment Facility
Phase II (Softening plus Additional Treatment) Costs
Trace 6262

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars, Annualized over 50 Years)	Least Expensive Technology for Treatment to Reach Water Quality Objective*
Valley City	\$5,540,327	\$407,807	Well
Fargo	\$10,998,250		lon Exchange
Grand Forks	\$17,246,671	\$1,269,477	lon Exchange
Grafton	\$536,079	\$39,459	Treatment of Park River
Orayton	\$582,538	\$42,879	Ion Exchange
Pembina	\$292,354	\$21,519	Ion Exchange
Morris	\$1,980,010		Ion Exchange
_etellier	\$2,537,378		lon Exchange
TOTAL	\$39,713,606	\$2,923,203	

^{*}Notes: Ion Exchange refers to the treatment of the existing water source to without-outlet concentrations of total hardness and TDS.

Table J-6
Municipal Water Treatment Facility
Phase II (Softening plus Additional Treatment) Costs
Trace 6600

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars, Annualized over 50 Years)	Least Expensive Technology for Treatment to Reach Water Quality Objective*
Valley City	\$5,540,327	\$407,807	Well
Fargo	\$6,744,364		Ion Exchange
Grand Forks	\$8,406,893	\$618,807	Ion Exchange
Grafton	\$535,162	\$39,392	Treatment of Park River
Drayton	\$320,636	\$23,601	Ion Exchange
Pembina	\$185,845	\$13,680	Ion Exchange
Morris	\$938,042	\$69,047	Ion Exchange
Letellier	\$1,198,617	\$88,227	Ion Exchange
TOTAL	\$23,869,886	\$1,756,993	

^{*}Notes: Ion Exchange refers to the treatment of the existing water source to without-outlet concentrations of total hardness and TDS.

Table J-7
Municipal Water Treatment Facility
Phase II (Softening plus Additional Treatment) Costs
Trace 7352

Municipal Water Treatment Facility	Present Worth Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars)	Annualized Cost for Treatment to Without-Outlet Concentrations of Total Hardness and TDS (1998 Dollars, Annualized over 50 Years)	Least Expensive Technology for Treatment to Reach Water Quality Objective*
Valley City	\$5,540,327	\$407,807	Well
Fargo	\$7,959,255		Ion Exchange
Grand Forks	\$11,934,928		Ion Exchange
Grafton	\$531,576		Treatment of Park River
Drayton	\$460,203	\$33,874	Ion Exchange
Pembina	\$239,140	\$17,602	Ion Exchange
Morris	\$1,453,369		Ion Exchange
Letellier	\$1,869,302		lon Exchange
TOTAL	\$29,988,100	\$2,207,337	

^{*}Notes: Ion Exchange refers to the treatment of the existing water source to without-outlet concentrations of total hardness and TDS.

Well refers to the installation of groundwater wells and the treatment of the water, if appropriate, to without-outlet concentrations of total hardness and TDS.

Rural Water refers to the connection to the rural water system and the treatment of the water, if appropriate, to without-outlet concentrations of total hardness and TDS.

Treatment of Park River refers to using the Park River as the primary water source and the treatment of the water to without-outlet concentrations of total hardness and TDS.

The water quality objective is to treat the water source to without-outlet concentrations of total hardness and TDS.

Appendix K

References

- American Water Works Association. 1990. Water Quality and Treatment, 4th Edition.
- American Society of Civil Engineers, American Water Works Association. Technology Transfer Handbook. United States EPA. 1996. *Management of Water Treatment Plant Residuals*. U.S. EPA/625/R-95/008.
- AScI Corp/AScI Duluth. 1998. *Toxicity Evaluation of Ambient Waters from Sheyenne River, Devils Lake, and East Devils Lake.* Submitted to USACE, St. Paul, MN, August, 1998.
- Ayers, R.S. 1976. Water Quality for Agriculture, Irrigation and Drainage Paper #29. Food and Agriculture Organization of the United Nations.
- Bergsrud, Fred and James Linn. *Water Quality for Livestock and Poultry*. University of Minnesota Extension Service, 1990.
- Boyles, Stephen, Kurt Wohlgemuth, George Fisher, Darnell Lundstrom, and Ladon Johnson. *Livestock and Water.* North Dakota State University Extension Service, June 1988.
- Davidson, H., R. Macklenburg, and C. Peterson. 1988. *Nursery Management Administration and Culture, Second Edition*. Prentice Hall, Englewoods Cluffs, New Jersey.
- Dirr, M.A. 1990. Manual of Woody Landscape Plants: Their Identification, Ornamental Characteristics, Culture, Propagation and Uses. Stipes Publishing Company, Champaign, IL.
- Engineering News-Record, June 28, 1998.
- Franzen, David, Carl Fanning, and Terry Gregoire. 1994. *Managing Saline Soils in North Dakota*. NDSU Extension Service.
- Gumerman, R.C., Culp/Wesner/Culp. November 1984. *Estimation of Small System Water Treatment Costs*. Prepared for the U.S. Environmental Protection Agency. EPA/600/12-84/184a.
- Hart, B.T., P. Baily, R. Edwards, K. Hortle, K. James, A. McMahon, C. Meredith, and K. Swadling. 1991. *Effects of Salinity on River, Stream, and Wetland Ecosystems in Victoria, Australia*. Water Research 24(9): 1103-1117.
- Hendrickson, J.C. 1990. *Salinity and Fish Reproduction in the Devils Lake Basin, North Dakota*. M.S. Thesis, North Dakota State University, Fargo, N.D.
- Hightshoe, G.L. 1988. *Native Trees, Shrubs, and Vines for Urban and Rural America*. Van Nostrand Reinhold, New York.
- Koel, T.M. 1993. Fertilization and Hatching Success of Fishes in the Sulfate-saline Waters of Devils Lake, North Dakota. M.S. Thesis. North Dakota State University, Fargo, N.D.

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- National Academy of Science. *Nutrients and Toxic Substances in Water for Livestock and Poultry.* NAS, 1974.
- North Dakota Agricultural Statistics Service, 1998, North Dakota Agricultural Statistics No. 67, North Dakota State University and U.S. Department of Agriculture.
- North Dakota Article 33-16. *Control, Prevention, and Abatement of Pollution of Surface Water.* Chapter 33-16-02 Standards of Water Quality for State of North Dakota.
- North Dakota State Water Commission. County Groundwater Studies.
- Peterka, John J. 1971. Effects of Saline Waters upon Survival of Fish Eggs and Larvae and upon the Ecology of the Fathead Minnow in North Dakota. Research Project Technical Completion Report. North Dakota Water Resources Research Institute, Fargo, North Dakota. 11 pp.
- Rhoades, J.D., Ph.D. Telephone interview. United States Salinity Laboratory, Riverside, CA.
- Rhoades, J.D., A. Kandiah, and A.M. Mashali. 1992. *The Use of Saline Waters for Crop Production, Irrigation and Drainage Paper #48.* Food and Agriculture Organization of the United Nations.
- Rieniets, J.P. and J.L. Millard. 1987?. *Use of Saline Solutions to Improve Fertilization of Northern Pike (Esox Lucius) Eggs.* National Fishery Center, Valley City, North Dakota.
- Rosen, C.J., P.M. Bierman, and R.D. Eliason. 1998. *Soil Test Interpretation and Fertilizer Management for Lawns, Turf, Gardens, and Landscape Plants.* Extension Bulletin, University of Minnesota.
- Soil Conservation Service, St. Paul, MN, 1976. Irrigation Guide for Minnesota.
- Teitge, J.E., D.R. Mount, and D.D. Gulley. 1994. *The GRI Freshwater STR Model and Computer Program: Overview, Validation, and Application.* Gas Research Institute, Chicago, IL.
- United States EPA. *Process Design Manual for Land Treatment of Municipal Wastewater*. EPA 625/1-81-013.
- USGS. Water Resources Investigations 81-51. 1981. Designation of Principal Water-Supply Aquifers in Minnesota.
- United States Salinity Laboratory. 1954. *Diagnosis and Improvement of Saline and Alkali Soils, Agriculture Handbook #60.*

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